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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

1952 ST. LOUIS MEETING

AT

WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI

November 28–29, 1952

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NOVEMBER 28, 1952 Vol. 27, No. 5

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AMERICAN PHYSICAL SOCIETY

ST. LOUIS MEETING, NOVEMBER 28–29, 1952

THE **1952 Thanksgiving meeting of the American Physical Society** will be held in St. Louis, in the buildings of Washington University, on Friday and Saturday, November 28 and 29, 1952. We shall be celebrating two important anniversaries. The transfer of the Thanksgiving meeting from its customary habitat of Chicago is due to to the fact that our distinguished host institution, of which the Chancellor is one of our Past Presidents, is celebrating its centennial throughout this academic year. One of the major events in the history of the world, the first functioning of the first nuclear reactor (in the West Stands of the athletic field of the University of Chicago), occurred ten years lacking four days before the date of the ceremony at which we shall commemorate it on Friday afternoon.

Hotels. To quote from the summons card: "Rooms have been reserved for our members at the Forest Park, Chase, and Park Plaza hotels . . . all reservations are however to be made by writing to the Reservation Manager at the Chase Hotel." It is not known whether rooms will still be available when this Bulletin appears.

The most direct conveyance from the hotels to the University is the westbound Lindell bus (93). It stops at the corner of Lindell and Kingshighway, which is at the Chase Hotel and near the Park Plaza; and at the corner of Euclid and Lindell, which is one block north of the Forest Park Hotel. Alight at Lindell and Skinker, which is at the front entrance to the campus. Allow twenty minutes for the trip. There are also streetcars three blocks north of the Chase; they are marked University (11) or University-Clayton (14); board at Waterman and Kingshighway and alight at Limit Way.

The **registration desk** will be located in Crow Hall. All members and guests are asked to register and frequently to consult the nearby blackboard for notice of messages.

The **commemoration of the first reactor** will be held in Brown Hall on the Friday afternoon. The speakers will be A. H. Compton, Enrico Fermi, E. P. Wigner, and W. H. Zinn. All were concerned in the event which the ceremony will recall. It is not to be assumed that their remarks will pertain exclusively to it.

Our **Division of Electron Physics will hold a Symposium** entitled "Physical Electronics" on Saturday morning; the participants will be L. Apker, J. B. Johnson, and D. Alpert.

Fourteen invited papers appear on the general programme: the speakers are G. F. Chew, T. L. Collins, Bernard Hamermesh, R. H. Hildebrand, J. R. Huizenga, Erling Jensen, Vivian A. Johnson, G. C. Phillips, H. T. Richards, R. D. Sard, J. A. Simpson, Jonathan Townsend, J. A. Van Allen, and K. M. Watson.

One hundred and thirty-six contributed papers are distributed among fourteen sessions. Nuclear physics and non-nuclear physics are about evenly balanced; what is really surprising is that they are only two contributed papers on cosmic rays!

The **banquet of the Society** will be held on the Starlight Roof of the Chase Hotel at seven o'clock on Friday evening. The price will be $4.25, including taxes and tips. Tickets will be available at the registration desk until 2 P.M. on Friday. Those who may arrive later but wish to be sure of getting their tickets may mail their checks with the reservation form printed on the inside back cover page of this Bulletin. Tickets reserved but not paid for will be considered available for distribution to the first comers after 2 P.M.. The after-dinner speakers will be A. H. Compton, A. L. Hughes, and A. H. Weber.

The **council of the American Physical Society** will meet at 10:30 A.M. on Friday, November 28, in the Tower Room of Brookings Hall.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are

received at the office of the Society not later than Monday, November 24. The abstracts will not be printed. The titles of such papers as are accepted will be announced on a blackboard near the registration desk, and the papers will be given under the usual ten-minute rule at the end of Session C.

Prospective meetings of the Society are scheduled to be held at Inyokern on December 26–27 and Pasadena on December 29–30; at Cambridge on January 22–24; at Durham, North Carolina, on March 26–28; at Washington, D. C., on April 30 and May 1–2; at Rochester, New York, on June 18–20; and at Albuquerque, New Mexico, on September 2–5.

The **American Institute of Physics** announces that during 1953 it will send the journal *Physics Today* gratis to those on a distribution list which comprises all members of the Founder Societies, of which our Society is one. In the Director's words: "This service will be rendered without adding in any way to the financial burdens of the Society or its members. . . . One medium of communication going to all physicists is vitally needed if physicists are to gain the advantages of community action and meet the demands of professional responsibility. It is on these grounds that extraordinary measures seem justified to give *Physics Today* general circulation."

The **American Association for the Advancement of Science** announces that in its St. Louis Meeting of December 26–31 there will be, among many others, the following features of particular interest to physicists: a Symposium "Nuclear Science in Industry" (morning of December 29); a Symposium "Research Applications of Carbon 14" (afternoon of December 29); a Symposium "Magnetic Resonance and its Applications" (morning of December 30); and the address "The Human Value of Physical Science" to be given on the evening of December 29 by A. H. Compton as Retiring Vice-President of Section B of the A.A.A.S. Further information may be obtained from the A.A.A.S. at 1515 Massachusetts Avenue NW, Washington 5, D. C.

Titles and abstracts of the papers contributed to our St. Louis meeting are printed hereinafter, and will reappear in identical form in a subsequent issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, December 12, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Write out your corrections in the form "instead of .... read ...."; do *not* send in your abstracts marked with corrections, and do *not* add anything.

Speakers must retrieve their lantern slides before leaving the room in which they spoke. The Local Committee must not be burdened with the trouble and expense of saving and returning them.

KARL K. DARROW, *Secretary*,
American Physical Society,
Columbia University
New York 27, New York

EPITOME OF THE 1952 ST. LOUIS MEETING

(Personal names are those of invited speakers.)

Friday Morning

A. Address of welcome (A. H. Compton) and response (E. Fermi). Van Allen, Simpson; cosmic rays. Brown.

B. Reactions of transmutation. Loudermann.

C. Electron emission. Post-deadline papers, if any. Wilson.

D. Atomic and molecular spectra; magnetic resonance. Crow 101.

E. Hamermesh, Phillips; apparatus of nuclear physics. Rebstock.

Friday Afternoon

G. Commemoration of the first functioning of a nuclear reactor on December 2, 1942. Compton, Fermi, Wigner, Zinn. Brown.

H. General physics. Loudermann.

K. Solid-state physics, I. Rebstock.

Friday Evening

Banquet of the American Physical Society. Starlight Roof, Chase Hotel.

Saturday Morning

P. Symposium of the Division of Electron Physics: Physical Electronics. Apker, J. B. Johnson, Alpert. Brown.

Q. Beta-emitters, helium through cadmium. Loudermann.

R. Watson, Chew, Hildebrand, Huizenga. Wilson.

S. Neutron physics; general nuclear physics. Rebstock.

T. Fluid dynamics; cryogenics. Crow 101.

Saturday Afternoon

V. Beta-emitters from caesium onward; nuclear scattering. Loudermann.

W. Sard, Richards, Collins, Jensen. Rebstock.

X. V. A. Johnson; solid-state physics, II. Brown.

Y. Townsend; luminescence. Crow 101.

Z. Theoretical physics. Wilson.

PROGRAMME

FRIDAY MORNING AT 10:00

Brown Hall

(A. L. HUGHES presiding)

Address of Welcome by CHANCELLOR A. H. COMPTON of Washington University
Response by Vice-President ENRICO FERMI of the American Physical Society

Cosmic Rays

Invited Papers

A1. Cosmic-Ray Intensity above the Atmosphere near the Geomagnetic Pole. J. A. VAN ALLEN, *University of Iowa.* (30 min.)

A2. Properties of Cosmic-Ray Intensity Variations. J. A. SIMPSON, *University of Chicago.* (30 min.)

Contributed Papers

A3. Recurring Daily Cycles of Nucleonic Component Intensity.* W. H. FONGER, J. W. FIROR, AND J. A. SIMPSON, *University of Chicago.*—A variation of neutron intensity with a period of one solar day has been found by averaging data over a period of ~65 days. The detectors are lead-paraffin piles containing BF_3 proportional counters to measure the local neutron production from the nucleonic component.[1] Measurements were obtained at geomagnetic latitudes 48°N and 0.5°S at an atmospheric depth of 680 g-cm^{-2}. The mean counting rates at 48°N and 0.5°S were 620 and 380 counts per minute, respectively. After pressure correction the averaged cycles are similar to sine functions with peak to peak amplitude ~1 percent and with maxima near local noon. Using the data at 48°N, significant departures from the *average* cycle have been found for individual days. It has also been found that these departures persist for intervals of 2–3 days and reoccur. The results are insensitive to choice of barometric coefficient.

* Assisted by the Office of Scientific Research, A.R.D.C., U. S. Air Forces.

[1] Simpson, Fonger, and Wilcox, Phys. Rev. **85**, 366 (1952).

A4. Mass Measurements of Heavy Mesons. D. T. KING, NATHAN SEEMAN, AND MAURICE M. SHAPIRO, *Naval Research Laboratory.*—Particles of mass 1400±140 m_e have been observed to originate in apparent nucleon-nucleon interactions of medium energy. The determinations of mass have been derived from measurements of multiple scattering and of grain density on long "gray" tracks associated with collisions of energetic particles with the nuclei of light atoms in photographic emulsions carried high in the atmosphere by free balloons. The accuracy of the mass determinations has been established by corresponding measurements on similar tracks attributable to protons and associated with the disintegration of heavy nuclei in the emulsion. The apparent decay in flight of one of the heavy mesons is described. The relation of the present measurements to those of previous experiments at M.I.T. and Bristol is discussed.

FRIDAY MORNING AT 10:15

Loudermann Hall

(F. B. SHULL presiding)

Reactions of Transmutation

B1. Angular Distribution of (d,t) Reactions.* S. T. BUTLER and E. E. SALPETER, *Cornell University.*—As was recently pointed out,[1] the forward part of angular distributions[2,3] from (d,t) (and also (t,d) (d,He^3) and (He^3,d)) reactions can be analyzed by a method closely analogous to that employed previously[4] for (d,p) reactions. The theoretical distribution is a product of two factors: (1) an oscillating term, identical with that appearing in the (d,p) formula, which depends on the angular momentum transfer; (2) a form factor, directly connected with the momentum space wave function of the triton, which decreases monotonically with angle. An approximate knowledge of the triton wave function is sufficient for determining spin and parities from (d,t) reactions which may be more convenient than the equivalent (p,d) reactions. Further, an accurate determination of (d,t) distributions would furnish direct information on the triton wave function. An analysis of a recent experimental angular distribution[5] for $Be^9(d,t)Be^8$ will be presented. Further possible experiments favorable for investigating the triton wave function will be discussed.

* Supported in part by the ONR.
[1] S. T. Butler and E. E. Salpeter, Phys. Rev. **88**, 133 (1952).
[2] F. A. El Bedewi, Proc. Phys. Soc. (London) **65**, 64 (1952).
[3] H. W. Fulbright *et al.*, private communication.
[4] S. T. Butler, Proc. Roy. Soc. (London) **A208**, 559 (1951).

B2. Angular Distribution and Differential Cross Section of $Li^6(n,\alpha)H^3$.† J. B. WEDDELL AND J. H. ROBERTS, *Northwestern University.*—Photographic plates loaded with enriched

Li^6 were exposed to unidirectional neutrons at energies 1.1, 1.5 Mev.[1] The angular distributions of the tritons of the tritons are plotted as functions of the angle φ_0, in the center-of-mass system, between the triton and neutron, and fitted to expansions of the form $A+B\cos\varphi_0+C\cos^2\varphi_0$. Plates were also exposed to two groups of neutrons, of energy 0.6 Mev and either 1.1 or 1.5 Mev. The total length of the tracks having $\varphi_0<33°$ or $\varphi_0<68°$ was determined, and from comparison of the two resolved groups of tracks we compute the differential cross section, integrated from 0° to 33° or 68°, relative to the values[2] at 0.6 Mev, 33°, 0.17 barn; 0.6 Mev, 68°, 0.27 barn. Preliminary results are 1.1 Mev, 33°, 0.068 barn; 1.5 Mev, 33°, 0.16 barn; 1.5 Mev, 68°, 0.27 barn. Corrections are made for thermal background and for the probability that each track obeys the selection criteria. Work now in progress will extend the results to 2.0 and 2.5 Mev.

† Work performed under AEC Contract.
[1] G. R. Keepin, Jr., and J. H. Roberts, Rev. Sci. Instr. **21**, 163 (1950).
[2] J. M. Blair and R. Holland (private communication).

B3. The Spin of the 7.4-Mev State of Li^7.† W. O. Solano and J. H. Roberts, *Northwestern University*.—We have made a remeasurement of the angular distribution of the tritons from the reaction $Li^6(n,\alpha)$ for 270-kev neutrons. Calculation of the angular distribution $I(\theta)$ assuming spin 5/2 yields a relationship for the ratio R, of the resonance part of the total absorption cross section to the nonresonance part, in terms of the coefficients of the angular distribution.[1] The unpublished absorption cross-section measurements of Blair and Holland show R to be about 3. Fitting the measured angular distribution of tritons in the c.m. system with a function of the form $A+B\cos\theta+C\cos^2\theta$ gives $I(\theta)=0.0556+0.0197\cos\theta+0.0721\cos^2\theta$. Thus $R=3.1$, which is consistent with spin 5/2, as indicated by the total cross section. The measurements were made with Li^6 loaded Ilford *C*-2 nuclear emulsions, exposed to 270-kev neutrons from the Oak Ridge electrostatic generator. Improved techniques permitted a more positive identification of background due to thermal neutrons and a more precise assignment of the probability that a given track may fail to meet geometric selection criteria.

† Work supported by AEC Contract.
[1] M. Peshkin and A. J. F. Siegert, Phys. Rev. **87**, 735 (1952).

B4. Angular Distributions of Protons from the Reaction $F^{19}(d,p)F^{20}$.† H. W. Fulbright, D. A. Bromley, and J. A. Bruner, *University of Rochester*.—A Teflon (CF_2) target was bombarded with 3.6-Mev deuterons from the Rochester 26-inch cyclotron, and the angular distributions of the resulting proton groups were determined using an ionization chamber detector. Table I gives the angular momentum transfer (determined by comparison with the Butler curves) and the cross sections corresponding to the indicated levels in F^{20}. These F^{20} states were found to have even parity, and the ground-state spin was determined to be 1.

Table I.

Ground state	$l_n=0$ and 2	$\sigma=0.92\pm0.18$ mb/sterad (at 45°)
0.65-Mev level	$l_n=2$	$\sigma=7.15\pm1.4$ mb/sterad (at 45°)
2.05-Mev level	$l_n=2$	$\sigma<8$ mb/sterad (at 45°)
3.49 and 3.53(?)-Mev level	$l_n=0$	$\sigma=116\pm23$ mb/sterad (at 7°)

† This work was supported in part by the AEC.

B5. Gamma-Rays from Proton Bombardment of Sodium[23].† J. W. Teener, L. W. Seagondollar, and R. W. Krone, *University of Kansas*.—Thick and thin targets of sodium were bombarded with protons at energy intervals of 5 kev over the energy range of 800 to 1700 kev. Thirteen resonances were found at energies in general agreement with earlier work.[1] Each resonance was investigated with the thin target at proton energy intervals of 1 kev. Target thicknesses were calculated by comparison of thick and thin target data by the method of Bernet *et al.*[2] Excitation levels in Mg^{24} were calculated. The energies of the gamma-rays emitted at several resonances were compared by means of a single NaI(Tl) crystal to the energies of gamma-rays from Cs^{137} and Sb^{124} and to the energies of gamma-rays from the bombardment of thick F^{19} and thick Li targets with 1.15-Mev protons. The results of the energy measurements are in disagreement with other recent work.[3]

† Work supported in part by the ONR.
[1] R. L. Burling, Phys. Rev. **60**, 340 (1941).
[2] Bernet, Herb, and Parkinson, Phys. Rev. **54**, 398 (1938).
[3] Stelson, Preston, and Goodman, Phys. Rev. **86**, 629 (A) (1952).

B6. Electrostatic Analysis of Nuclear Reaction Energies.* D. J. Donahue,† K. W. Jones, M. T. McEllistrem, and H. T. Richards, *University of Wisconsin*.—A spherical electrostatic analyzer[1] has been used to measure the reaction energies listed in Table I. The incident particle energy is defined by a cylindrical electrostatic analyzer and the reaction particles are observed at 135° to the incident beam. In addition, the $B^{11}(p,\alpha)Be^8$ reaction has been used as a source of Be^8. Preliminary data indicate that the Be^8 break-up energy is 96 ± 3 kev.

Table I.

Reaction	Q (Mev)	Energy of excited state
$Na^{23}(p,\alpha)Ne^{20}$	2.379 ± 0.003	...
$Na^{23}(p,\alpha)Ne^{20*}$	0.745 ± 0.002	1.634 ± 0.004
$Na^{23}(p,p')Na^{23*}$	-0.439 ± 0.001	0.439 ± 0.001
$Mg^{24}(p,p')Mg^{24*}$	-1.371 ± 0.002	1.371 ± 0.002
$Al^{27}(p,p')Al^{27*}$	-0.843 ± 0.002	0.843 ± 0.002
$Al^{27}(p,\alpha)Mg^{24}$	1.594 ± 0.002	...
$Al^{27}(p,\alpha)Mg^{24*}$	0.228 ± 0.003	1.366 ± 0.004

* Work supported in part by the AEC and in part by Wisconsin Alumni Research Foundation.
† Now at General Electric Company, Hanford Works, Richland, Washington.
[1] Browne, Craig, and Williamson, Rev. Sci. Instr. **22**, 952 (1951).

B7. Magnetic Analysis of Protons from $Cr^{52}(d,p)Cr^{53}$ and $Ni^{58}(d,p)Ni^{59}$.* C. E. McFarland, M. M. Bretscher, and F. B. Shull, *Washington University*.—A uniform-field magnetic spectrometer of 42.25-cm mean radius was used to analyze the protons from the $Cr^{52}(d,p)Cr^{53}$ and $Ni^{58}(d,p)Ni^{59}$ reactions. The incident deuteron beam was accelerated by the Washington University cyclotron, and its energy was about 10.2 Mev. The protons were observed at an angle of 90° relative to the deuteron beam and were detected by photographic plates. A series of 12 or more plates exposed at graduated values of magnetic field covered the interesting range of proton momentum thoroughly. The deuteron energy was determined from the same sets of plates by an analysis of the $O^{16}(d,d)O^{16}$ reaction. The targets were isotopically-concentrated Cr_2O_3 and NiO loaned by the Atomic Energy Commission. Eight well-defined proton groups from the chromium target yield Q values of 5.70, 5.16, 4.73, 3.41, 3.04, 2.50, 2.05, and 1.60 Mev. Six well-defined proton groups from the nickel target yield Q values of 6.77, 6.35, 3.69, 2.20, 1.57, and 1.11 Mev, and it seems possible that at least one unresolved group would yield a Q of about 3 Mev.

* Assisted by the joint program of the ONR and AEC.

B8. The Yield of Long-Range α-Particles from $F^{19}(p,\alpha)O^{16}$. E. B. Paul and R. L. Clarke, *Chalk River Laboratories*.—The yield of long-range α-particles from the proton bombardment of fluorine has been studied at 90° to the proton beam using the Chalk River Electrostatic Accelerator. The measurements were made at proton energies which ranged from 0.8

to 2.0 Mev, and evaporated CaF_2 targets less than 30 kev thick were used. The α-particles were analyzed magnetically and detected in a proportional counter. In addition to previously reported[1] resonances, two new resonances in the long-range α-particles yield were observed at proton energies of 1.72 and 1.92 Mev. These occur at the same energies as two of the resonances reported[2] in the yield of pairs from the 6.05-Mev state of O^{16}, and the ratio of the yields at these two resonances in the observed α-particle yield curve is very different from that reported for the pair yield curve.

[1] Chao, Tollestrup, Fowler, and Lauritsen, Phys. Rev. **79**, 108 (1950).
[2] G. C. Phillips and N. P. Heydenberg, Phys. Rev. **83**, 184 (1951).

B9. Energy Distributions of Photoprotons from Heavy Elements.* W. E. STEPHENS, M. E. TOMS, E. E. CARROLL, JR., AND G. ROSENBLUM, *University of Pennsylvania*.—The energy distributions of the photoprotons ejected from indium, cerium, and bismuth by 24-Mev betatron x-rays have been measured and compared with calculated distributions based on Courant's direct photoeffect and Weisskopf's evaporation process. The direct photoprotons can in these cases be partially distinguished from the evaporated protons in the basis of energy distribution. The results of such an analysis give observed yields in particles per mole per roentgen unit and comparable calculated yields as shown in Table I. The agreement

TABLE I.

Observed	Direct protons	Evaporated protons	
Bi	$3.5 \cdot 10^4$	$0.4 \cdot 10^4$	
Ce	$6.6 \cdot 10^4$	$3.8 \cdot 10^4$	
In	$7.5 \cdot 10^4$	$4.5 \cdot 10^4$	
Calculated		$r_0 = 1.5$	$r_0 = 1.3$
Bi	$1.5 \cdot 10^4$	$1.3 \cdot 10^4$	$0.3 \cdot 10^4$
Ce	$0.7 \cdot 10^4$	$0.07 \cdot 10^4$	$0.02 \cdot 10^4$
In	$2 \cdot 10^4$	$1 \cdot 10^4$	$0.5 \cdot 10^4$

seems reasonable except for cerium and indicates the importance of the direct photoeffect for the (γ, p) process in heavy nuclei.

* Assisted by the Air Research and Development Command and by the joint program of the ONR and AEC.

B10. Photoprotons from Mo^{100} and Mo^{92}.* W. A. BUTLER AND G. M. ALMY, *University of Illinois*.—The energy and angular distributions of photon-protons from concentrated isotopes Mo^{100} and Mo^{92}, irradiated with betatron x-rays of 22.5-Mev maximum energy, have been determined from the tracks of the protons caught in nuclear emulsions. For Mo^{100} it had been shown from (γ, p) and (γ, n) induced activities that the binding energy of a proton B_p is 2.4 Mev greater than that of a neutron B_n, and that the ratio $\sigma(\gamma, p)/\sigma(\gamma, n)$ is about 100 times that expected from a statistical model calculation. The latter result was confirmed by a comparison of the directly observed proton spectrum with a calculated spectrum. This implies that the protons are mainly emitted in a direct process without the usual competition with neutron emission. The shape of the observed proton spectrum requires, however, that the directly emitted protons leave the residual nucleus with an exponential energy distribution. In angular distribution most of the protons from 5 Mev to 12 Mev (maximum possible) show marked asymmetry, peaked forward of 90°, similar to the distribution found for the small anisotopic components in Cu and Co. For Mo^{92} B_n exceeds B_p by 5.1 Mev and the proton energy and angular distributions have the same small but definite departures from those predicted from the statistical model which have been found in other nuclei for which $B_n > B_p$.

* Supported by the joint program of ONR and AEC.

B11. Relative Photofission and Photoneutron Cross Sections for U^{238}.* JOHN R. HUIZENGA, *Argonne National Laboratory*, AND ROBERT B. DUFFIELD, *University of Illinois*.—The yields of the two reactions U^{238} (gamma, n) U^{237} and U^{238} (gamma, fission) produced by x-rays from the University of Illinois 22-Mev betatron have been measured as a function of betatron energy. The ratio of the number of fissions to the number of U^{237} atoms was 0.35 at 8 Mev, decreased to 0.25 and 12 Mev, and then increased to 0.42 at 22 Mev. These data are interpreted to show that with betatron energies in excess of 12 Mev, an increasing fraction of the U^{237} atoms formed are left with sufficient excitation energy that they can undergo fission or emit an additional neutron.[1] These secondary processes increase the total fission yield and decrease the U^{237} yield.

* This work supported by the joint program of the AEC and ONR.
[1] J. S. Levinger and H. A. Bethe, Phys. Rev. **85**, 577 (1952).

FRIDAY MORNING AT 10:15

Wilson Hall

(N. S. GINGRICH presiding)

Electron Emission

C1. Use of Ba^{140} in Studies of Oxide Coated Cathodes.* J. H. AFFLECK AND L. V. HOLROYD, *University of Missouri*.—Some experiments on oxide coated cathodes using the radioisotope Ba^{140} as a tracer are presented. An oxide cathode of BaO containing Ba^{140} is used as an evaporator in a tube containing several movable receivers for collecting the evaporated BaO. The activity of the receivers indicates the amount of Ba deposited. An improved tube design permits making the activity measurements through a thin glass bubble window in the side of the tube. The results show that the time rate of deposition is constant for a given temperature. By using a similar tube, one can measure the rate at which "free" Ba, produced at the interface, diffuses to the surface and is evaporated to the anode. The technique of spraying radioactive $BaCO_3$ is introduced in order to introduce cathodes of normal coating weight and density containing appreciable Ba^{140} (0.25 mc/g). These cathodes are operated under quiescent conditions for various periods of time. After life test the activity of the cathode interface is measured. This activity is related to the interface thickness, and its rate of formation can be determined as a function of life.

* Supported in part by the ONR.

C2. Effect of the Evaporation Products from a BaO Coated Cathode on the Secondary Emission of MgO Thin Films.* B. V. HAXBY AND P. WARGO, *University of Minnesota*.—The exposure of a secondary emission surface to the evaporation products of an oxide coated cathode gradually poisons the surface. With the use of a cathode coating including a radioactive tracer of Ba^{140}, this effect has been measured as a function of the number of equivalent atom layers of Ba deposited on the secondary emitter, a thin MgO film on Mg–Ag alloy. The cathode consisted of single BaO coating on a 499-Ni base. The overburden thickness is given as equivalent atom layers of

Ba because the relative concentration of Ba and BaO coming off the cathode is not known. The secondary yield increased initially, reaching a maximum after the deposition of about one equivalent atom layer. At about three layers δ has returned to its initial value. The yield then decreases more or less uniformly until approximately fifteen equivalent layers have been laid down, beyond which little change occurs. These results are independent of the primary electron energy.

* Supported by the U. S. Army Signal Corps.

C3. Rate of Evolution of the Constituents of an Oxide Coated Cathode as a Function of the Molar Composition of the Coating.* R. W. PETERSON, *University of Minnesota.*—Simple planar diodes containing radioactive isotopes of Ba or Sr in cathode coatings having varying molar compositions of Ba and Sr are processed, aged, and run on life test. The cathode based nickel used is No. 499 passive nickel. A removable electrode is provided to shield the anode from the cathode during processing and aging so as to distinguish between cathode products evolved during processing and aging and that evolved during life. Tubes are aged for four hours at cathode brightness temperature of 855°C and run on life for 118 hours at the same temperature. It is found that over a range of molar compositions of Ba from 20 percent to 50 percent the evolution of Ba is essentially independent of molar composition. Results of these experiments will be reported.

* Supported by U. S. Army Signal Corps. This work is an extension of the work reported by W. F. Leverton and W. G. Shepherd, J. Appl. Phys. **22**, 787–793 (1952).

C4. Analysis of the Schottky Deviation for the Highly Refractory Metals.* D. W. JUENKER, G. S. COLLADAY, AND E. A. COOMES, *University of Notre Dame.*—A summary has been made of all the available thermionic Schottky deviation data on the highly refractory metals, tungsten, tantalum, and molybdenum. Comparison with a corrected version of the Guth-Mullin theory[1,2] makes possible the following conclusions: (a) The mirror-image form is the correct one for the surface barrier. (b) The phase of periodic deviations is independent of field, indicating that the image potential is terminated close to the surface. (c) The magnitude of the deviation phase is less than that computed for the "box model" by about a quarter-period for all the metals investigated. This indicates a potential form near the surface somewhat different from the abrupt box model, and a close similarity in this form for the three highly refractory metals. (d) Experimental values for the magnitude of the surface reflection coefficient are not inconsistent with the box model, and suggest that the departure of the real potential shape from this model cannot be extreme.

* This research was sponsored by the U. S. Navy Bureau of Ships.
[1] E. Guth and C. J. Mullin, Phys. Rev. **59**, 575 (1941).
[2] E. Guth and C. J. Mullin, Phys. Rev. **61**, 339 (1942).

C5. The Patch Effect for the Thermionic Emission from Polycrystalline Tantalum.* E. A. COOMES, J. A. DEZOTEUS, AND J. F. WHALEN, *University of Notre Dame.*—The patch modifications in the Schottky effect have been studied for tantalum as a function of thermal aging, and the effect of grain growth has been separated from that of thermal etching. When 3-mil tantalum filaments are heated on either ac or dc, crystal grains several times the wire diameter appear within the first 10 hours. These grains develop on continued thermal aging; associated with this growth, the high-field break in the Schottky plot moves from an $E^{\frac{1}{2}}$ of about 100 (volt/cm)$^{\frac{1}{2}}$ to about 25 (volt/cm)$^{\frac{1}{2}}$ during 26 hours of heating. Within about 15 hours of aging at 2500°K, the characteristic thermal etch appears on some grains of the dc heated filaments, but not on those heated on ac. The Schottky plots for the dc case now show an additional high-field break at about 200 (volt/cm)$^{\frac{1}{2}}$ and a low-field break at about 120 (volt/cm)$^{\frac{1}{2}}$. Herring and Nichols[1] suggest that this anomalous region due to a superstructure on the crystal grains might appear.

* This research was sponsored by the U. S. Navy Bureau of Ships.
[1] C. Herring and M. H. Nichols, Revs. Modern Phys. **21**, 185 (1949), Chapter 2.

C6. A Technique for Secondary Electron Emission Measurements. E. J. SCOTT, *U. S. Naval Ordnance Laboratory.*—A new technique suitable for the study of secondary electron emission from metals and insulating materials is described. The usual methods employ either the pulsed primary beam or the pulsed collection techniques. These fail for very good insulators. The new method employs collection pulses synchronized with two separate primary beam pulses, one of which produces the secondary electrons while the other erases the charge on the emitting surface. In this manner it is possible to control the rate of charging of the surface of the material under investigation.

C7. Secondary Electron Emission of MgO Single Crystals with Excess Oxygen.* K. C. NOMURA, *University of Minnesota.*—The secondary electron yield of MgO single crystals has been measured for several densities of excess oxygen. The measurements of δ were made using a pulse technique. The density of the excess O_2 was determined from optical absorption measurements using Pohl's formula,[1] which has been verified experimentally by Weber[2] for this case. As the oxygen content decreased from 9×10^{17} cm^{-3} to 3×10^{17} cm^{-3} the value of δ_{max} increased from 5.7 to 6.7. The value of the secondary emission coefficient for a stochiometric crystal was found to be 8.

* Work supported by U. S. Army Signal Corps.
[1] R. W. Pohl, *Einführung in die Optik* (Frederick Ungar Publishing Company, 1943), S184, Gl. 204, 205.
[2] H. Weber, Z. Physik **130**, 392–402 (1951).

Post-Deadline Papers, if Any

FRIDAY MORNING AT 10:15

Crow Hall, 101

(G. E. PAKE presiding)

Atomic and Molecular Spectra; Magnetic Resonance

D1. The Hyperfine Structure of the Ground State of Aluminum. HIN LEW AND GÜNTER WESSEL, *National Research Laboratories, Ottawa.*—The measured ratios of the hyperfine structures of the ^2P ground states of Ga, In, and Tl differ from the theoretical ratios for a single p electron. It has been shown[1,2] that this is due to a disturbance by higher configurations, and that the magnetic dipole interaction constant $a(^2P_{\frac{1}{2}})$ is less disturbed than $a(^2P_{\frac{3}{2}})$, while the effect on the quadrupole interaction constant $b(^2P_{\frac{3}{2}})$ is negligible. Consequently, nuclear quadrupole moments should be calculated

with the average value of $1/r^3$ taken from $a(^2P_{\frac{1}{2}})$ rather than $a(^2P_{\frac{3}{2}})$. Since there did not exist a very accurate determination of $a(3p^2P_{\frac{1}{2}})$ of Al^{27}, we undertook to measure it by the atomic beam magnetic resonance method, and have found $\Delta\nu = 3a = 1506.14 \pm 0.05$ Mc/sec. This result, along with the measurements on the $^2P_{\frac{1}{2}}$ state by Lew,[3] shows that the effect of perturbation is small for aluminum. This fits in well with the observed decrease of configuration interaction from Tl to Ga. The influence on the quadrupole moment of Al will be briefly discussed.

[1] E. Fermi and E. Segrè, Rend. reale accad. d'Italia **4**, 18 (1933); Z. Physik **82**, 729 (1933).
[2] G. E. Koster, Phys. Rev. **86**, 148 (1952).
[3] Hin Lew, Phys. Rev. **76**, 1086 (1949).

D2. Hyperfine Structures of the Resonance Lines of Indium 1.* G. V. DEVERALL, K. W. MEISSNER, AND G. J. ZISSIS, *Purdue University.*—In the process of developing an atomic beam light source for use at high oven temperatures, an investigation of the indium resonance lines at 4511A and 4101A was carried out. The employment of a well-collimated atomic beam, excited by electron impact, and of a Perot-Fabry interferometer made it possible to resolve clearly all components of the hyperfine structures of both lines. The complete resolution of the line 4511A has not been accomplished with other light sources.[1-3] The high spectroscopic accuracy led to values of the hyperfine splittings of the $5^2P_{\frac{1}{2},\frac{3}{2}}$ terms which agree within ± 0.0004 cm^{-1} with the values obtained by microwave methods.[4,5] Furthermore, a precise value for the hyperfine splitting of the $6^2S_{\frac{1}{2}}$ term was obtained, namely 0.2814 ± 0.0005 cm^{-1}.

* Supported in part by ONR contract.
[1] H. Schuler and T. Schmidt, Z. Physik **104**, 468 (1937).
[2] D. A. Jackson, Z. Physik **80**, 59 (1933).
[3] J. S. Campbell and K. F. Bacher, Phys. Rev. **38**, 1906 (1931).
[4] A. K. Mann and P. Kusch, Phys. Rev. **77**, 427 (1950).
[5] P. Kusch and H. M. Foley, Phys. Rev. **74**, 250 (1948).

D3. The Molecular Constants of Methyl Alcohol. E. V. IVASH* AND D. M. DENNISON, *University of Michigan.*—Values for the molecular constants of methyl alcohol have been obtained using the observed microwave data. The calculations are based on the theory of Burkhard and Dennison[1] for the asymmetric molecule with hindered rotation, and utilize the measurements of Hughes, Good, and Coles.[2] Values have been obtained for the barrier height, for the moments of inertia, and for the inter-atomic distances giving, on the whole, good agreement with the experimental results. Some of these calculated values are: (1) a barrier height of 374.8 cm^{-1}; (2) 5.333×10^{-40} g cm^2 for the moment of inertia of the methyl group about its symmetry axis; and (3) a displacement of 0.079A of the oxygen atom from the methyl group symmetry axis away from the hydrogen atom.

* Now at the University of Texas, Austin, Texas.
[1] D. G. Burkhard and D. M. Dennison, Phys. Rev. **84**, 408 (1951).
[2] Hughes, Good, and Coles, Phys. Rev. **84**, 418 (1951).

D4. Electronic Spectra of Diatomic Molecules: The Oxygen Molecule. FAUSTO G. FUMI* AND ROBERT G. PARR, *Carnegie Institute of Technology.*—A scheme is proposed for the computation of electronic energy levels of diatomic molecules with fair accuracy and minimum labor. The theoretical LCAO MO method including configuration interaction is employed. However, the energies of the asymptotic dissociation products for the various states are taken from atomic data,[1,2] and the calculation of the interaction energies is simplified by the formal neglect of differential overlap in the electronic repulsion terms.[2] The first application is made to O_2, and the results are in substantial agreement with experiment and with a previously more involved calculation by Moffitt.[3]

* Research Corporation Postdoctoral Fellow.
[1] W. Moffitt, Proc. Roy. Soc. (London) **A210**, 245 (1951).
[2] R. Pariser and R. G. Parr, J. Chem. Phys. (to be published).
[3] W. Moffitt, Proc. Roy. Soc. (London) **A210**, 224 (1951).

D5. Normal Coordinate Analysis of 1, 3, 5-Trifluorobenzene. ELDON E. FERGUSON, *University of Oklahoma.*—A normal coordinate analysis has been carried out for the nonplanar and the totally-symmetric vibrations of the 1,3,5-trifluorobenzene molecule, based on the frequency assignments of Nielsen, Liang and Smith[1] and utilizing results from Crawford and Miller's normal coordinate treatment of benzene.[2,3] The analysis of the nonplanar vibrations has furnished strong support for Nielsen, Liang and Smith's tentative assignment of the lowest A_2'' fundamental and has led to the conclusion that their value for the highest E'' fundamental is too high. The spectral data have been re-examined, and a reasonable new assignment has been given for this E'' fundamental. A plausible reinterpretation of several of the observed combination and overtone bands is given which is consistent with the change in assignment of the E'' fundamental. The analysis of the totally-symmetric planar vibrations has yielded a value of 6.37×10^5 dynes/cm for the CF bond stretching force constant. This is appreciably higher than that found in fluorinated saturated hydrocarbons.

[1] Nielsen, Liang, and Smith, Disc. Faraday Soc. No. 9, p. 177 (1950).
[2] B. L. Crawford, Jr., and F. A. Miller, J. Chem. Phys. **17**, 249 (1949).
[3] F. A. Miller and B. L. Crawford, Jr., J. Chem. Phys. **14**, 282 (1946).

D6. Vibrational Spectra and Calculated Thermodynamic Properties of CCl_2CF_2Cl and CCl_3CFCl_2.* J. RUD NIELSEN AND C. Y. LIANG, *University of Oklahoma,* AND D. C. SMITH AND MORRIS ALPERT, *Naval Research Laboratory.*—The infrared spectra of liquid CCl_2CF_2Cl, and of CCl_3CFCl_2 as glass and in CS_2 solution, have been obtained in the region from 2 to 38μ with the aid of LiF, NaCl, KBr, and KRS-5 prisms. The Raman spectra of these compounds in the liquid state, at 25° and 120°C, respectively, were photographed with a three-prism glass spectrograph of linear dispersion 15A/mm at 4358A. Relative intensities and depolarization ratios were measured for all but the weakest Raman bands. Complete assignments of fundamental vibration frequencies have been made, the spectra have been interpreted in detail, and thermodynamic functions have been calculated.

D7. The High Pressure Inversion Spectrum of ND_3 near 1500 Mc. G. BIRNBAUM AND A. A. MARYOTT, *National Bureau of Standards.*—The absorption of ND_3 associated with the inversion spectrum of the ground vibrational state has been measured at a number of frequencies between 1100 and 2600 Mc and at pressures between 3 and 800 mm Hg. Fine structure appears to be obliterated by pressure broadening even at the lowest pressure. A reasonably good representation of the data for pressures up to 100 mm was obtained with a single Van Vleck-Weisskopf shape factor, provided the line breadth $\Delta\nu$ and the resonance frequency ν_0 were adjusted for each pressure. It was not possible to fit data above 100 mm in this manner. Initially ν_0 has the value 0.0526 cm^{-1} but has shifted noticeably at 10 mm and becomes substantially zero at 80 mm. By comparison with NH_3, this shift occurs at pressures roughly fifteen-fold lower, a result in the direction expected from Margenau's theory.[1] $\Delta\nu/p$ decreases with increasing pressure, the rate of change being considerably greater at the lower pressures. These results will be compared with similar results for NH_3, and their significance will be discussed.

[1] H. Margenau, Phys. Rev. **76**, 1423 (1949).

D8. Variation of Mutual Collision Diameters with Mix Ratio in Binary Mixtures in Microwave Pressure Broadening. L. C. JONES, A. V. BUSHKOVITCH, C. A. POTTER, AND A. G. ROUSE, *Saint Louis University.*—It has been previously found[1] that mutual collision diameters of foreign perturbers determined from pressure broadening of ammonia microwave absorption lines vary with mix ratio. Extensive measurements of the collision diameters of oxygen and helium in binary mixtures with ammonia have now been made using gas

mixtures that were chemically analyzed at various pressures to correct the mix ratio. The variation with mix ratio was again observed. A least squares reduction of the data gave the following results for the variation of collision diameters measured in angstroms: oxygen-ammonia, $b_{12}=4.71-8.52\times10^{-3}$ (percent oxygen); helium-ammonia, $b_{12}=2.47-2.98\times10^{-3}$ (percent helium).

[1] Potter, Bushkovitch, and Rouse, Phys. Rev. **83**, 987 (1951).

D9. The Possible Microwave Absorption in the Molecules Belonging to the Point Groups $D_{2d}\equiv V_d$ and T_d.* VENKATESWARLU PUTCHA† AND MASATAKA MIZUSHIMA, *Duke University*.—It is shown that pure rotational absorption in the molecules belonging to the point group $D_{2d}\equiv V_d$ (allene, etc.) is possible if the molecule is in an excited doubly degenerate vibrational state. The approximate positions of these lines, as calculated from the B value obtained from the infrared data, fall in the microwave region in the case of allene and allene-d_4. The same type of absorption is also possible in the molecules belonging to the point group T_d if they are in the excited triply degenerate (F_2) vibrational states. The matrix element of dipole moment corresponding to our transition is calculated, and it was shown to be proportional to the second derivative of the dipole moment with respect to the corresponding normal coordinate. (The first derivative will also contribute some through the effect of anharmonicity.) It is interesting that the above matrix element of dipole moment is about the same as that of the overtone vibrational bands.

* Work supported by contract with Air Force Cambridge Research Center.
† Also written as Putcha Venkateswarlu.

D10. Anomalous Results in an Attempt to Determine the Spin of Si^{29}.† R. H. SANDS AND G. E. PAKE, *Washington University*.—An attempt has been made to determine the spin of Si^{29} through comparison of its integrated absorption intensity with that of an equal number of I^{127} nuclei. The sample consisted of 0.4295 g of enriched SiO_2 amorphous powder, obtained on loan from Oak Ridge National Laboratory, in a physical mixture with KI powder. The sample was placed in a Pound type spectrometer, and the magnetic field was adjusted so that both resonances could be recorded at the same frequency without any instrumental adjustments. The ratio of the I^{127} integrated intensity to that of Si^{29} was found to be about 4.3 ± 0.5 over a range of experimental conditions. Since the intensity is proportional to $I(I+1)$ and the spin of I^{127} is 5/2, the ratio should be 11.7, 2.3, or 1.0 if the Si^{29} spin were 1/2, 3/2, or 5/2, respectively. Possible systematic errors will be discussed, and a number of silicon-containing materials not yielding a resonance will be listed. Anomalies in Si^{29} resonances have also been found by the Stanford group.[1]

† Assisted by the joint program of the ONR and AEC.
[1] S. Dharmatti (private communication).

D11. Nuclear Magnetic Relaxation in Polytetrafluoroethylene and Polyethylene.* C. W. WILSON, III, AND G. E. PAKE, *Washington University*.—The thermal relaxation time T_1 and the inverse line width parameters T_2 have been measured in the two linear polymers, polyethylene and polytetrafluoroethylene (Teflon), over a temperature range from -180°C to about $+200$°C. The experiments present complexities which can be explained by assuming that each substance possesses two values of T_1 and two values of T_2. A suggested interpretation, based upon the fact that these polymers are stable mixtures of crystalline and amorphous regions, permits one to estimate the degree of crystallinity using the experimental data. The first-order transition[1] at 20°C in Teflon was studied with particular interest. No effect was observed on the resonance attributed to amorphous regions, which can be reasonably well described using the theory of Bloembergen *et al.*[2] for fluids. The resonance from crystalline regions narrows in the neighborhood of the transition. Possible motions of the polymer chains which are consistent with the data will be discussed.

* Assisted by the joint program of the ONR and AEC. The large electromagnet and part of the electronic equipment were provided through a grant from the Research Corporation.
[1] Rigby and Bunn, Nature **164**, 583 (1949).
[2] Bloembergen, Purcell, and Pound, Phys. Rev. **73**, 679 (1948).

D12. Homogeneity Mapping of a Permanent Magnet Field for Chemical Effect Studies in Nuclear Resonance.* C. R. BRUCE (introduced by G. E. Pake), *Washington University*.—The magnetic field in the gap of a permanent magnet has been plotted in considerable detail using the proton resonance from mineral oil samples as small as one cubic millimeter in volume. This has been done for several planes parallel to the pole faces. These contour plots show the field to be quite inhomogeneous and intricate in the planes near the iron of the pole faces. However, the homogeneity improves rapidly, and the detail of the pattern disappears in planes slightly further from the iron. The plots were used to find homogeneous regions suitable for observing the chemical shift of the proton resonances arising from nonequivalent nuclei within the same molecule.[1] Charts of the field contours will be shown with special emphasis placed upon the effect of proximity to the iron.

* Assisted by the joint program of the ONR and AEC.
[1] Arnold, Dharmatti, and Packard, J. Chem. Phys. **19**, 507 (1951).

FRIDAY MORNING AT 10:15

Rebstock Hall

(W. H. ZINN presiding)

Invited Papers

E1. Measurement of Neutron-Capture Gamma-Rays. BERNARD HAMERMESH, *Argonne National Laboratory*. (30 min.)

E2. Accurate Determination of Disintegration-Energies. G. C. PHILLIPS, *Rice Institute*. (30 min.)

Apparatus of Nuclear Physics

E3. Fast Neutron Scintillation Spectrometer. MARSHALL R. CLELAND, *National Bureau of Standards*.*—The Monte Carlo sampling procedure has been used to evaluate a proposed spectrometer for neutrons with energies above 1.0 Mev. The efficiency is shown to be about 0.15 percent and the energy resolution about 10 percent for 14.0-Mev neutrons. This instrument employs a cylindrical phosphor, 5 centimeters in diameter and 5 centimeters long, composed of a half-and-half

mixture of phenylcyclohexane and methyl borate activated with 3–5 grams of *p*-terphenyl and 10–15 milligrams of diphenylhexatriene per kilogram of phosphor.[1] Only those events are recorded in which the neutron is first thermalized by elastic collisions and then captured by boron. The capture criterion strongly favors neutrons that lose most of their energy at the first collision, hence the narrow pulse-height distribution. The mean time interval between the recoil proton pulse and the boron capture pulse is shown to be about 2.0 microseconds with 18.8 percent boron-10 and about 0.25 microsecond with 94 percent boron-10. The efficiency and energy resolution are shown to be the same for normal and enriched boron. The delayed pulse distinguishes fast neutrons from most other radiations. Although it does not rule out inelastic scatterings, it assures that the neutron was not absorbed at high energy. The spectrometer is nondirectional.

* Supported by the Office of Basic Instrumentation.
[1] C. O. Muehlhause and G. E. Thomas, Phys. Rev. **85**, 926 (1952).

E4. A Velocity Spectrometer Using a Microsecond Neutron Shutter. F. G. P. SEIDL, D. J. HUGHES, AND H. PALEVSKY, *Brookhaven National Laboratory.**—A neutron shutter (commonly called a "chopper") has been designed and put into operation as part of a time of flight spectrometer, which separates pile neutrons in a collimated beam according to their various times of flight between the chopper and a detector 20 meters away. The chopper action depends upon a fast-spinning rotor which, when spinning at 6000 rpm, periodically produces neutron bursts, each having a full width at half-maximum of one microsecond. Since detector pulses are electronically sorted into various 2 microsecond channels, according to time after each burst, a resolution of 0.2 microsecond/meter results. The open-beam counting rates per channel are never less than 10 counts/minute above background. Curves of neutron transmission *vs* energy will be shown. Since the chopper rotor has been designed to spin at 12,000 rpm, we plan to run at higher resolution in the near future. The spectrometer will be used to study transmission effects for neutrons from 1 ev to 10 kev.

* Work carried out under contract with AEC.

E5. Extrapolated Ionization Ranges for 10- to 250-kv Protons in Various Gases. T. JORGENSEN, E. JONES, AND C. J. COOK. *University of Nebraska.*—An analyzed beam of protons is admitted into a gas filled stopping cell through a differential pumping "window," and the ionization produced along the beam is measured by a double grid ionization chamber. This chamber is so arranged that its transverse dimension may be varied. It has been found that the range is uniquely determined for an effective chamber radius larger than the ionization envelope of the beam in the stopping gas. The results of the measurements are estimated to be known within 2 percent. The range energy curves may be closely approximated by an empirical relationship, $R=kE^n$, $E<E_0$, $n\approx\frac{3}{2}$, $R=C(E+E_1)^{\frac{1}{2}}$, $E>E_0$, where k, C, n, E_0, and E_1 are interrelated constants dependent upon the stopping medium.

E6. An Activity Ratio Method for Measuring the Energy Stability of Betatrons. MILTON BIRNBAUM, ERIC M. HARTH, LEO SEREN, AND RALPH TOBIN. *Naval Research Laboratory.*—For nuclear threshold measurements, betatrons employ a magnetic flux integrator to trigger the expansion circuit at a time in the magnetic cycle which corresponds to the desired peak energy of bremsstrahlung. In practice, betatrons using these magnetic flux integrators exhibit a day to day variation in energy stability of 100 to 200 kilovolts. We have used a method for measuring the stability of the betatron which depends only on nuclear activations, and is therefore independent of the gamma-ray monitor. At a peak bremsstrahlung energy of 11.4 Mev, the radioactivity induced in copper by the reaction $Cu^{63}(\gamma, n)Cu^{62}$ is changing at the rate of 0.8 percent per kilovolt change in peak energy, while the radioactivity induced in silver from the reaction $Ag^{107}(\gamma, n)Ag^{106}$ is changing at the rate of only +0.11 percent per kilovolt. The ratio of the copper activity to the silver activity thus changes by +0.69 percent per kilovolt. We have irradiated copper and silver discs simultaneously and observed the ratio of the induced activities. Using this ratio method, we find the day to day stability of our betatron to be 40 kilovolts at 11 Mev, and the accuracy of the activity ratio method is better than 20 kilovolts.

E7. Measurement of Ionizing Radiation by Frequency Variation. HANS KOHN RICHARDS. *Oak Ridge National Laboratory.*—A method has been developed to measure ionizing radiation by the frequency variation of a rf oscillator operating at a nominal frequency of 2.3 megacycles. An electrometer of variable capacitance is a component of the frequency determining network, the capacitance variation being produced by the movement of a metal vane suspended by means of a quartz fiber between two electrode pairs. The position of the vane between the electrode pairs is determined by an electric charge applied to the vane. Electrostatically, the system represents two capacitances in parallel of the order of 4 to 5 $\mu\mu$f, while the rf capacitance consists of two capacitances in series. Ionizing radiation produces a leakage of the charge from the vane and, therefore, variations in capacitance and frequency. The frequency is measured using a standard quartz crystal oscillator. One mr/hr produces a frequency variation of approximately 20 cycles/minute. Dose rates of gammas, betas, and neutrons have been measured. By connecting the vane through several megohms to different capacitances, the system can measure dose rate of widely different magnitudes. This system makes possible the monitoring of numerous locations from a single remote station.

E8. Evapor-ion Pump.* R. G. HERB, ROBERT H. DAVIS, AJAY S. DIVATIA, AND D. SAXON, *University of Wisconsin.*—A new type of high vacuum pump to replace diffusion pumps and traps has been developed for use on the accelerating tube of a new electrostatic generator now under construction. After initial roughing by a fore pump the system is sealed. Titanium in wire form is evaporated continuously inside a cylindrical metal chamber 7 in. i.d., 24 in. high. The gettering by titanium on the wall of the chamber results in pumping action. In order to pump components that do not respond to gettering action, it is necessary to ionize the gas inside the chamber by electron bombardment and drive the gas ions so formed into the wall by an electric field, where they are buried in fresh layers of evaporated metal. Cylindrical geometry is used for ionization. Qualitative tests indicate that H_2, N_2, O_2, CO_2, SF_6, CCl_2F_2, C_2H_4, NH_3, CH_4 are readily pumped by the gettering action alone; in order to pump the inert gases argon and helium ionization is necessary. On a sealed-off system which had not been baked and which utilized O ring gaskets, a pressure of 5×10^{-7} mm Hg was maintained. Pumping speeds for various gases are being investigated as a function of the temperatures of the gettering surfaces.

* Work supported by the Wisconsin Alumni Research Foundation and the AEC.

FRIDAY AFTERNOON AT 2:00

Brown Hall

(H. D. SMYTH presiding)

Commemoration of the First Functioning of a Nuclear Reactor on December 2, 1942

G1. A. H. COMPTON, *Washington University.*
G2. ENRICO FERMI, *University of Chicago.*
G3. E. P. WIGNER, *Princeton University.*
G4. W. H. ZINN, *Argonne National Laboratory.*

FRIDAY AFTERNOON AT 2:30

Loudermann Hall

(J. B. JOHNSON presiding)

General Physics

H1. Charge States of a Helium Beam in Hydrogen, Helium, Air, and Argon. ELIAS SNITZER, *Department of Physics and Institute for Nuclear Studies, University of Chicago* (introduced by Samuel K. Allison).—Measurements have been made of the fractions of a helium beam in the He^0, He^+, and He^{++} charge states in the energy range of 100 kev to 480 kev for beams which have attained charge equilibrium in hydrogen, helium, air, and argon. For the four gases, the He^0 and He^+ components are equal for helium energies of 148 kev, 145 kev, 98 kev, and 115 kev, respectively. The ratios of the electron loss to electron capture cross sections between He^+ and He^{++} fitted a simple power dependence of $\sigma_l/\sigma_c = \alpha V^m$, where V is the velocity of the helium in the beam and m equals 6.1, 5.1, 5.2, and 6.3, respectively, for the four gases studied. For electron capture and electron loss between He^0 and He^+ the exponent m varies from 2.6, 2.0, 2.8, and 3.4 at 100 kev to 4.0, 4.0, 4.3, and 5.1 at 450 kev.

H2. The Separation of Incident and Emitted Radiations in a Solar Furnace by Means of Rotating Sectors. WILLI M. CONN* AND GENE BRAUGHT,† *Rockhurst College.*—A paraboloidal mirror is used for concentrating radiation from the sun in a sample placed near the focal area. The sample is heated to a temperature at which an equilibrium is established between the amount of radiant energy incident on the sample and the losses from it. The temperature is controlled by varying the effective aperture of the mirror by means of a cylindrical shutter traveling along the optical axis of the mirror. The temperature of the sample is measured with an optical pyrometer or a radiation pyrometer equipped with color filters. It was found necessary to shut off the incident radiation from the sample during the measurement of temperature in order to obtain correct data (checked with standard materials). This is accomplished by rotating sectors traveling at 2500 revolutions per minute. One sector of special shape is located near the sample and another sector near the telescopic system. The calibration and use of the sectors in connection with mirrors of maximum apertures 60 in. and 120 in. and focal lengths 25¾ in. and 34 in. is presented.

* Now with the Research Department, Gustin-Bacon Manufacturing Company, Kansas City, Missouri.
† Now with St. Louis University, St. Louis, Missouri.

H3. Contribution of Doppler Effect to Radiation Exchange in the Stratosphere. GILBERT N. PLASS AND DANIEL I. FIVEL, *The Johns Hopkins University.*—The principal contribution to the total line width in the upper stratosphere comes from the Doppler effect. In order to investigate radiative transfer throughout our atmosphere, it is necessary to know the line absorption coefficient $k(\nu)$, when both the Lorentz and Doppler widths ($\Delta\nu_L$ and $\Delta\nu_D$) contribute to the total width. The general term of the expansion of $k(\nu)$ in powers of $\Delta\nu_L/\Delta\nu_D$, as well as the asymptotic expansion in inverse powers of the frequency, has been obtained. From these results the atmospheric transmission functions have been derived for a planetary atmosphere when both $\Delta\nu_L$ and $\Delta\nu_D$ contribute to the line width and when the variation of $\Delta\nu_L$ with pressure is considered. For the earth's atmosphere it is found that the transmission function calculated from the Lorentz shape alone for either strong or weak lines is not changed appreciably by the Doppler effect even at heights where $\Delta\nu_D$ is considerably larger than $\Delta\nu_L$. This is because almost all the radiation transfer takes place in the far wings of a strong line where the Lorentz broadening determines the line shape. For a weak line only the total line strength is of importance. Applications to laboratory absorption measurements will be discussed.

H4. On the Theory of Interstellar Grains. BERTRAM DONN, *Wayne University.*—Interstellar space is known to contain a mixture of atoms (mainly hydrogen) and small solid grains, the whole having an over-all density of approximately 10^{-24} g/cm³.[1] Among the major problems of interstellar matter are those concerned with the origin, evolution, and structure of the grain. This paper discusses one aspect of the general problem, namely, the interaction between the gas and the grains under present conditions. This limited analysis nevertheless requires consideration of a variety of problems associated with surface phenomena, for which no completely satisfactory treatment is available. Among the problems which will be discussed are condensation; evaporation and adsorption for contaminated surfaces; surface mobility; chemical reactions; and heterogeneous catalysis. The application of the limited available results to the case of interstellar matter suggests that the grain will be stable throughout most of space but incapable of further growth. In order to extend the theory and improve the tentative conclusions, further work must be carried out on the basic physical and chemical processes which comprise the gas-grain interaction in space.

[1] See chapter on "Interstellar matter" in *Astrophysics*, edited by Hynek (McGraw-Hill Book Company, Inc., New York, 1951).

H5. The Analysis of a Bridged-T Network by Use of Laplace Transformations. CORRE WILLIAMS, *Consolidated-Vultee Aircraft Corporation*, AND HERBERT D. SCHWETMAN, *Department of Physics, Baylor University.*—The analysis of a simple bridged-T network through the use of Laplace transformations is demonstrated. The resonance frequency, the phase angle, and the output voltage are determined for several values of terminating resistance and network components.

H6. The Entropy of Fusion of Monatomic Liquids. N. K. POPE, *Chalk River Laboratories.*—A relation has been obtained between the entropy of fusion of monatomic liquids and the number of a particular set of neighbors in the liquid. In general, the set of neighbors involved is the nearest set that shows evidence of increase of radial separation on melting. Usually this is not the first, but the second, or even the third set of neighbors. The relationship has been deduced by using a model in which it is assumed that at sufficiently high temperatures one of the neighbors of a given atom in a solid may move outwards to a new equilibrium position. An order-disorder theory of the melting process has been formulated, which identifies the liquid with a state in which every atom has, on the average, one of its neighbors moved out to the new equilibrium position. X-ray and neutron diffraction patterns of liquids give the number and mean positions of the first, second, and third neighbors. In many cases where this information is available, the number of neighbors measured in the liquid state, in the set which is displaced outward on melting, agrees with the number calculated from the measured values of the entropy of fusion.

H7. Respiration of Plant Tissue Cultures as a Function of X-Ray Dose. MARK W. JONES, *University of Florida.*—Tissue cultures of corn root tips, grown in White's culture medium augmented by 10^{-5} mg IAA per liter nutrient, were subjected to x-ray doses of 100, 200, 400, 800, and 1400 roentgens. The mean oxygen uptake of the tissues, measured by standard Warburg techniques, decreased with increasing dose. It ranged from 8.7 to 3.8 $\mu l O_2$/mg/hr for doses from 0 to 1400 roentgens. Analyses of variance and covariance of the respiration *versus* dose of unirradiated tissues and irradiated tissues show the observations to be highly significant. Concomitant observations of dry weights indicate that their use for the arbitrary correction of respiration rates of different weight cultures is not completely justified for the analysis of covariance between different series of observations.

H8. Research on Comfort, Relaxation, and Quality of Sleep. T. SMITH TAYLOR AND L. W. MAX,* *U. S. Testing Company.*—This research was undertaken to determine some methods of measuring the relative comfort experienced by subjects sleeping on different mattresses. The research was directed towards measuring physical properties of the individual during sleep that would give the relative degrees of relaxation and hence the relative comfort experienced. The physical properties measured were heartbeat, muscle tensions, brainwaves, skin temperature, electrical skin resistance, and number of movements. Both men and women have been used as sleeping subjects. By comparing statistically the various values of the various properties measured on one mattress with those while sleeping on another, these were found to be significantly different. The results showed definitely that for a large number of subjects the subjects experienced greater relaxation and hence more comfort on one mattress than they did on others. This paper gives the progress of the research during the last three years. A later paper will give more complete details of the methods and the ultimate findings.

* Head of Department of Physiology, Dental College, New York University, Special Consultant.

H9. Design and Construction of a Universal Test Mattress. NORMAN L. TAYLOR AND T. SMITH TAYLOR, *U. S. Testing Company.*—A Universal Test Mattress has been constructed in which the individual components are rubber bellows instead of springs. Each bellows reacts independently of the others. If a given bellows is compressed, a definite increase in pressure is produced which is measured by a gauge which is proportional to the change in volume. By use of the test mattress, the average distribution of weight in each 3½-in. section of the body has been determined for several individuals. This is the first time that body weight distribution has been determined on live subjects. Since the reaction of each section of the mattress from head to foot can be varied, it is possible to obtained the optimum conditions of pressure variation in the several bellows necessary to give maximum relaxation to the sleeping subject. The mattress is being used in connection with others in an extensive research on mattress comfort.

H10. Angular Points in Densities of Water *vs* Temperature. GEORGE ANTONOFF AND RAYMOND MADRAZO, JR.—The best methods of demonstrating kinks are the following: (I) As was shown elsewhere,[1] kinks are well seen if $d^1(d=d_1-d_v)$ is plotted against T. For kinks in water see Antonoff *et al.*[2] (II) At low T the method (I) becomes less sensitive. Thus we plot X *vs* T with a strongly diminished parameter X, and the kinks appear as the intersection of nearly straight lines. For water the values for X are $X=4$, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 12,288, 24,576, 75,728, and 147,402 at 4.9°C. (III) The same kinks are easily visible in d_1 and d_v *vs* T curves at high T. The temperatures are counted downwards from an arbitrary zero near the critical point. The equations $d_1=A_1+B_1T-CT^2$ and $d_v=A_2-B_2T+CT^2$, which are valid between two adjacent kinks with given constants, show very good agreement with experimental data. These equations are based on points between two kinks as indicated by method (I). Calculations beyond the two adjacent kinks show a marked departure from continuity. Above $X=64$ the method is not sensitive. Mademoiselle Olivier (Thèse, Strasbourg, 1952) used similar equations starting from low T and failed to reveal kinks. The use of statistical methods is not practicable, because the experimental errors cannot be seen on the graph.

[1] Compt. rend. 3/XII (1951).
[2] Antonoff, Zakimac, Urmanczy, and Madrazo, Phys. Rev. **86**, 586(A) (1952).

FRIDAY AFTERNOON AT 2:30

Rebstock Hall

(V. A. JOHNSON presiding)

Solid-State Physics. I

K1. Shot Noise in Germanium Filaments. R. H. MATTSON AND A. VAN DER ZIEL, *University of Minnesota.*—Herzog and van der Ziel's measurements[1] of the noise ratio n(=total noise power over thermal noise power) of a 10,000-ohm germanium filament have been extended to higher frequencies, and the accuracy of the measurements has been improved considerably.

We find that the formula, $n=1+AI^2/f+BI^2/[1+(f/f_0)^2]$, with $f_0=150$ kc, $AI^2=9.3\times10^5$, $BI^2=54$, can account for all measurements at a dc current of 3 ma. As both electrons and holes are present and as each carrier should show shot effect, it must be concluded that both types of carriers have about the same life time. An application of the theory of shot noise in semiconductors shows that most of the noise comes from the electrons and that the electrons most likely originate from trapping centers located at a depth of about 0.22 ev below the bottom of the conduction band. Similar trapping centers have also been found in other investigations.[2]

[1] G. B. Herzog and A. van der Ziel, Phys. Rev. **84**, 1249 (1951).
[2] R. N. Hall, Phys. Rev. **87**, 387 (1952).

K2. Shot Noise in Semiconductors. A. VAN DER ZIEL, *University of Minnesota*.—The theory of shot noise in semi conductors has been developed for the case that both electrons and holes are present in the semiconductor. If the number N_e of free electrons and the number N_h of free holes in the sample are fluctuating independently, such that $(N_e-\bar{N}_e)^2=\alpha\bar{N}_e$ and $(N_h-\bar{N}_h)^2=\beta\bar{N}_h$, then the noise ratio n_s resulting from shot effect (=shot noise power over thermal noise power) is found to be

$$n_s=(e/kT)(V_0^2/d^2)\left[\frac{\alpha\mu_e\tau_e\sigma_e/(\sigma_e+\sigma_h)}{1+\omega^2\tau_e^2}+\frac{\beta\mu_h\tau_h\sigma_h/(\sigma_e+\sigma_h)}{1+\omega^2\tau_h^2}\right],$$

where d is the length of the sample, V_0 the dc voltage across it, μ_e and μ_h the electron and hole mobility, σ_e and σ_h the electron and hole conductivity, and τ_e and τ_h the electron and hole life time, respectively. This formula will be applied to several cases.

K3. The Flicker Noise Caused by an Interface Layer. W. W. LINDEMANN AND H. J. HANNAM.—When some tube types are aged while only a small current is drawn, a high resistance interface layer develops,[1] the resistance of which increases further with life. If the interface resistance becomes as high as a few hundred ohms, the noise resistance of the tube at low frequencies may have increased by as much as a factor 1000. The noise resistance is proportional to the square of the anode current, which suggests that the phenomenon may be explained by a spontaneous fluctuation in the resistance of the interface layer. Curves showing the increase in noise resistance as a function of time and the dependence of the noise resistance upon cathode temperature will be presented.

[1] A. Eisenstein, *Advances in Electronics* (1948), Vol. I, pp. 1–64.

K4. The Influence of Neutron Bombardment on the Low Temperature Atomic Heat of Silicon.* P. H. KEESOM, K. LARK-HOROVITZ, AND N. PEARLMAN, *Purdue University*.—The heat capacity of B.T.L. silicon below 5°K has been measured before and after fast neutron irradiation in the Oak Ridge reactor. Before bombardment the atomic heat included the lattice contribution and a term linear in temperature due to a degenerate carrier gas. The coefficient γ of the linear term observed for Si V corresponds to the impurity concentration (0.01 percent B by weight) if the effective hole mass is 0.8 the free electron mass. Hall measurements by H. Fritzsche between 4–300°K confirm this concentration. After bombardment the linear term disappeared in Si II and decreased by 75 percent in Si V, owing to carrier trapping by lattice defects produced by neutron irradiation.[1] Annealing ingot Si II at 780°K partly restored the original low temperature atomic heat. The Debye θ decreased after bombardment for both ingots, indicating a decrease in elastic constants[2] larger than expected from theory. See the data compiled in Table I.

TABLE I.

	Si II				Si V	
			Annealed			
	Original	Bombarded	up to 450°C	at 780°C	Original	Bombarded
θ (°K)	658	637	632	642	658	636
γ (joules/mole deg^2)	21.0×10^{-4}	1.55×10^{-4}	1.74×10^{-4}	13.7×10^{-4}	34.6×10^{-4}	9.26×10^{-4}

* Supported by Signal Corps and AEC contracts.
[1] H. M. James and K. Lark-Horovitz, Z. physik. Chem. **198**, 107 (1951).
[2] G. J. Dienes, Phys. Rev. **87**, 666 (1952).

K5. Some Electrical Characteristics of Crystalline Boron. WM. C. SHAW, D. E. HUDSON, AND G. C. DANIELSON, *Iowa State College*.—Micromanipulative techniques for mounting very small crystals with several spring loaded probes have been developed. The method makes use of a modified Chambers micromanipulator, a binocular microscope, and special tools. Crystals 0.01 cm long have been mounted with five spring loaded tungsten probes, allowing electrical conductivity and Hall coefficient measurements to be made over a wide range of temperature. The method has been applied especially to microscopic single crystals of boron. The electrical resistivity varied from about 10^6 ohm/cm at 25°C to less than 1 ohm/cm at 550°C. Preliminary measurements indicate a very small Hall coefficient.

K6. Adsorption of Oxygen on Zinc Oxide.* S. R. MORRISON,† *University of Pennsylvania*.—It has been shown that oxygen is adsorbed on zinc oxide. The total adsorption has not been measured; but it has been shown that when the zinc oxide is heated above 500°C, oxygen previously adsorbed on the sample is desorbed, leaving adsorption sites. The number of these adsorption sites prepared increases rapidly with increasing cleaning temperature. With a constant number of adsorption sites, it has been shown that the amount of oxygen adsorbed is maximum at about 425°C. It has been shown that the number of adsorption sites, if left unoccupied, decreases with time. Postulating that the interstitial zinc in the lattice are the adsorption sites, this effect has been interpreted as being due to the diffusion of the zinc atoms away from the surface. On the basis of this model, the activation energy for the diffusion of interstitial zinc has been calculated to be 1.2 ev.

* Supported by the ONR.
† Now at the University of Illinois.

K7. The Structure of the Surface of Glass and of Bi Films Deposited on Glass. J. J. ANTAL AND A. H. WEBER, *St. Louis University*.—The surface structure of glass has been studied by electron diffraction after deposition of a very thin layer of Bi on the glass to reduce charging. If less than 10A thick, the Bi contributes negligibly to the diffracted intensity or may be eliminated because of its preferred orientation. Radial distribution curves were computed from data obtained from the diffraction patterns by a combination of densitometry and visual examination. The annealed surface of commercially prepared soda-lime-silica glass (72 percent SiO_2, 14 percent Na_2O, 11 percent CaO) was examined. The radial distribution curves indicate that the structure of the glass surface is essentially a random network of Si and O atoms as found for the volume structure of vitreous silica by Warren.[1] Distances to alkali atoms were absent from the radial distribution curves, which indicated an absence of alkali atoms for a depth in the glass equal to the depth of penetration (always less than 10A) of the electrons—although migration of alkali atoms to the surface of a glass is well known. Electron diffraction and electron microscopic examination of the Bi films deposited on glass will also be reviewed.

[1] B. E. Warren, J. Appl. Phys. **8**, 645 (1937).

K8. Rates of Coloration of KCl and KBr During X-Irradiation at 78°K.* WILLIAM H. DUERIG AND JORDAN J. MARKHAM, *Applied Physics Laboratory, The Johns Hopkins University*.—When KCl and KBr crystals are x-rayed at 78°K, several color center bands appear, e.g., the F, F', V_0, V_1, and V_2 bands.

In order to gain further understanding of the nature of the imperfections responsible for these bands, their growth rates during x-raying at 78°K were measured. The rates were obtained under two conditions: (1) when the crystal was in the dark, and (2) when it was exposed to F' light. The results of these experiments will be presented and analyzed.

* This research was supported by the Bureau of Ordnance, United States Navy.

K9. A Theory of Successive Rotational Transitions in Crystals. THEODORE J. KRIEGER AND HUBERT M. JAMES, *Purdue University.*—Some crystals show successive phase transitions attributed to changes in rotational or orientational order, but no detailed calculations have previously been made on crystal models showing more than one orientational transition. A crystal model consisting of classical rotators with next-neighbor interaction energy, $E(\theta_{ij}) = AP_1(\cos\theta_{ij}) + BP(\cos\theta_{ij})$, has been treated in the Bragg-Williams and Bethe approximations. Depending on the magnitude of B/A, it shows a single second-order transition, a single first-order transition, two first-order transitions, or a second-order followed by a first-order transition as T rises. When two transitions occur, the upper transition temperature depends primarily on the value of B, the lower on the values of both A and B. Our results, together with the estimates of dipole and van der Waals forces in hydrogen halides made by Powles, enable one to understand qualitatively the variation of transition temperatures in the hydrogen and deuterium halides.

K10. Approximate Treatment of Order-Disorder Transitions in the Simple Cubic Ising Lattice. L. D. FOSDICK AND H. M. JAMES.—The approximation method previously applied to the square and triangular Ising arrays[1,2] has been applied to the simple cubic lattice. Attention is fixed on a certain site surrounded by six next-neighbors and twelve second-neighbors. Three weighting parameters, characterizing long- and short-range order, are used in computing the configuration probabilities. Three consistency relations determine these parameters as functions of the temperature and coupling energy. This method gives a Curie temperature $kT_c/V = 2.3145$ and a specific heat c, just below the Curie point given by $(c/k)|T_c \cong 2.58$, in close agreement with Kikuchi's results.[3] Correlations (the probability for finding parallel spins minus the probability for finding antiparallel spins) between spin pairs up to fifth neighbors have been computed. The results emphasize that long-range order persists in three-dimensional lattices for higher temperatures and lower short-range order than it does in two-dimensional lattices.

[1] H. M. James and L. D. Fosdick, Phys. Rev. **81**, 312 (1951).
[2] L. D. Fosdick and H. M. James, Phys. Rev. **85**, 714 (1952).
[3] R. Kikuchi, Phys. Rev. **81**, 988 (1951).

K11. A Cellular Calculation of the Band Structure for Barium Oxide. EARL L. STEELE* AND JAMES A. KRUMHANSL, *Cornell University.*—Electronic wave functions and energy levels have been calculated for the barium oxide crystal using methods similar to those developed by Ewing Seitz[1] and Von der Lage and Bethe.[2] The crystal is divided into cells (spheres) surrounding each atom, and a spherically symmetric potential including exchange is developed in each cell. Bloch-type one-electron wave functions were constructed from linear combinations of atomic-like functions, and boundary conditions were imposed where the spheres of neighboring atoms intersected. Energies for particular points in k space for the valence and conduction band were obtained. This calculation gives a minimum band gap of 3.4 ev between $k(000)$ in the conduction band and the $k(110)$ end point in the valence band; however, the minimum gap for optical transitions (constant k) is 7.3 ev for the $k(000)$ point. The self-consistent solution shows that the crystal is highly ionic.

* Now at the General Electric Electronics Laboratory, Syracuse, New York.
[1] D. H. Ewing and F. Seitz, Phys. Rev. **50**, 760 (1936).
[2] F. C. Von der Lage and H. A. Bethe, Phys. Rev. **71**, 612 (1947).

K12. The Calculation of Energy Bands in Crystals. G. PARZEN AND T. WAINWRIGHT, *University of Notre Dame.*—A method has been developed for calculating the energy levels of a crystal which will take into account the actual shape of the atomic polyhedra. The idea behind our approach is to find a variational principle for the energy levels of the crystal which involve only the Wannier functions instead of the usual Bloch wave functions. The hope is that such a variational principle will avoid the difficulties of having to fit the awkward boundary conditions on the surface of the atomic polyhdron and that at the same time the integrals arising will extend over a few cells of the crystal rather than over the entire crystal. The variational principle does not give $E(\mathbf{K})$ directly, but if $E(\mathbf{K})$ for a particular band is expanded in a Fourier series in $\mathbf{K}$, then our variational principle allows us to calculate the Fourier coefficients of $E(\mathbf{K})$ in this expansion. The method has been applied to a one-dimensional problem, and the results seem promising. We are now applying the method to lithium and sodium.

K13. Solids Subjected to a Constant Rate of Generation of Lattice Defects. JEROME ROTHSTEIN, *Signal Corps Engineering Laboratories.*—If a solid is subjected to a constant rate of lattice defect generation (e.g., by photon, electron, or nucleon irradiation), defect concentrations are produced which may exceed those characteristic of thermal equilibrium. At low temperatures, defect destroying mechanisms are largely ineffective; at high temperatures they reduce defect concentrations practically to equilibrium values. A simple kinetic treatment of Frenkel or Schottky thermal defects plus generated defects yields defect density decreasing as temperature rises from low values until a minimum defect density is reached. Thereafter defect density increases, approaching thermal asymptotically. The temperature range below minimum defect density exhibits anomalous dependence of defect concentration on temperature and hence possible anomalies in properties dependent on defects or disorder. Such possibilities include retrograde expansion coefficient, anomalous dip in specific heat, anti-Curie point (temperature below which disordered phase is stable), anomalous temperature dependence of diffusion rate, rate of solid-state chemical reactions, defect-dependent conductivity and photoconductivity in intrinsic semiconductors, density of traps and donors in phosphors and semiconductors, color centers and photoconductivity in alkali halides, internal friction, ultrasonic attenuation, etc. Clear-cut experiments without prohibitive difficulties seem feasible.

FRIDAY EVENING AT 7:00
Starlight Roof, Chase Hotel
(ENRICO FERMI presiding)

Banquet of the American Physical Society

After-dinner speakers: A. H. COMPTON, A. L. HUGHES, and A. H. WEBER

SATURDAY MORNING AT 9:45

Brown Hall

(A. L. HUGHES presiding)

Symposium of the Division of Electron Physics

Physical Electronics

P1. Photoelectric Emission from Solids. L. APKER, *General Electric Research Laboratory.* (40 min.)

P2. Experiments and Thoughts on Secondary Emission. J. B. JOHNSON, *Bell Telephone Laboratories* (now with *Edison Laboratory, Thomas A. Edison, Inc.*) (40 min.)

P3. Researches in Ultra-High Vacuum. D. ALPERT, *Westinghouse Research Laboratories.* (40 min.)

SATURDAY MORNING AT 10:00

Loudermann Hall

(L. M. LANGER presiding)

Beta-Emitters, Helium through Cadmium

Q1. Electron-Neutrino Angular Correlation in the Beta-Decay of He^6.† JAMES S. ALLEN AND W. K. JENTSCHKE, *University of Illinois.*—The energy spectrum of the recoil nuclei emitted during the beta-decay of He^6 has been investigated by means of a time of flight method. The beta-rays were recorded by a scintillation counter having a stilbene crystal, and an electron multiplier tube was used to detect the recoil nuclei. The detection of a beta-ray by the scintillation counter initiated the sweep of an oscilloscope, and the time of flight of the accompanying recoil nucleus was indicated by the position of a pulse on this sweep. In this experiment the angle between the directions of emission of the beta-rays and the recoil nuclei was limited to a range of approximately 100 to 180 degrees. The shape of the time of flight spectrum suggests a $1+(v/3c)\cos\theta$ electron-neutrino angular correlation corresponding to the tensor type of interaction. The experiment is being continued in order to increase the statistical accuracy of the data.

† Assisted by the joint program of the ONR and AEC.

Q2. Spectrometer Measurement on the High Energy Positrons of Sodium 22.* BYRON T. WRIGHT, *University of California at Los Angeles.*—Using a small solenoidal spectrometer,[1] a measurement of the ratio R of the transformation constant of the lower energy spectrum to that of the higher energy spectrum of positrons from Na^{22} was made. By careful attention to the shielding and baffles and by using an end-window Geiger counter seven millimeters in diameter and about 25 millimeters long as the detector, the background counting rate with an 0.3 millicurie source of Na^{22} was reduced to 0.1 counts per second. Momentum plots of the then observed spectra agreed with the expected shapes to a point well below the maximum on each curve (assuming the higher energy spectrum to have an allowed shape; this experiment yields no meaningful data on the details of the shape of the higher energy spectrum). The ratio R was obtained by averaging the ratios of the observed counting rates for four corresponding points near the maxima of the two spectra. The result is $R=1800\pm400$. The transformation constant for the decay of Na^{22} to the ground state of Ne^{22} is $4.7\pm1.0\times10^{-12}$ sec^{-1}, based on a half-life of Na^{22} of 2.60 years.[2]

* Supported in part by the joint program of the ONR and AEC.
[1] Byron T. Wright, Am. J. Phys. **20**, 230 (1952).
[2] L. J. Laslett, Phys. Rev. **76**, 858 (1949).

Q3. The High Energy Negatron Spectrum of Sc^{46}. J. A. WHALEN, F. T. PORTER, AND C. S. COOK, *Washington University.**—Investigation of the high energy negatron spectrum of Sc^{46} has been continued[1] since sources of higher specific activity have been made available from Oak Ridge. In addition to the internal conversion electrons, a weak continuous negatron spectrum is still observed in the momentum range above 350 kev. It is still not possible to eliminate completely the existence of any Compton electrons produced in the source. However, electrons whose intensity relative to the lower energy beta-spectrum and to the internal conversion lines is constant, independent of source thickness, have been found in the region beyond the highest Compton electron momentum. The energy of this beta-group cannot be greater than 1.2 Mev. The current measurements indicate that less than 0.1 percent of the beta-transitions go through the higher energy group. The total internal conversion coefficients $(K+L+M)$ are, from these measurements, 1.9×10^{-4} for the 0.88-Mev gamma and 8.8×10^{-5} for the 1.11-Mev gamma.

* Assisted by the joint program of the ONR and AEC.
[1] F. T. Porter and C. S. Cook, Phys. Rev. **81**, 640 (1951).

Q4. The Beta-Spectrum of S^{35}.* J. P. MIZE AND D. J. ZAFFARANO, *Iowa State College.*—The beta-spectrum of S^{35} [1] has been investigated with a proportional counter spectrometer whose geometric efficiency is ~100 percent. Our data yield a straight Fermi plot from the end point of the spectrum down to 10 kilovolts. The sources consisted of 0.005 microcurie of carrier-free S^{35} mounted on zapon films of 4 ± 2 $\mu g/cm^2$ surface density. The source films are supported within the counter volume parallel to and one inch away from the center wire. The cylindrical proportional counter is 24 inches long with an inner diameter of 8.5 inches and is filled with an argon-methane admixture to an absolute pressure of 40 lb/in.^{2}. Data were obtained with a one-channel differential discriminator. The associated electronic equipment was tested for linearity with a mercury relay type of pulse generator. X-rays were fired into the spectrometer through a beryllium window for energy calibration. Calibration and resolution of the spectrometer as well as results obtained with other sources will be discussed.

* This work was performed in the Ames Laboratory of the AEC.
[1] Heller, Sturcken, and Weber, Phys. Rev. **83**, 848 (1951). (This contains references to earlier papers.)

Q5. Excited Levels of Ti^{48}. PAUL L. ROGGENKAMP, CHARLES H. PRUETT, AND ROGER G. WILKINSON, *Indiana University.**—The disintegration scheme of the decay of 16-day V^{48} to Ti^{48} has been studied by scintillation counter methods, and spins and parities have been assigned to the levels. The angular correlation of the well-known cascade gamma-ray pair with energies of 0.99 and 1.32 Mev has been measured. The results support the assignment 0–2–4 for the corresponding levels. Interference from the correlation of the annihilation radiation at 180° is eliminated by the use of differential discriminators in each channel. A gamma-ray at 2.20 Mev appears in the scintillation spectrum and is found to be in coincidence with the annihilation radiation, but not with the cascade pair. Further evidence that this gamma-ray is not the crossover of the cascade pair has been obtained from magnetic beta-ray spectrometer studies of the positron spectrum. These measurements suggest positron emission to a level in Ti^{48} 2.20 Mev above the ground state. The positron-group involved in the decay to the 2.31-Mev level of Ti^{48} is found to have an end-point energy of 0.69 Mev. Shell model considerations and the angular-correlation measurements result in consistent assignments of the spins and parities for the ground states of Sc^{48} and V^{48} as well as for the 2.20-Mev level of Ti^{48}.

* Supported by the joint program of the ONR and AEC.

Q6. Atomic Excitation and Ionization Accompanying Orbital Electron Capture by Nuclei. H. PRIMAKOFF AND F. T. PORTER, *Washington University.**—The process of atomic excitation and ionization accompanying orbital electron capture by nuclei is treated on the basis of the general theory of β-decay using a configuration space representation for both nucleons and leptons. Quantitative expressions are obtained (a) for the total number of double holes produced in the K shell due to K capture accompanied by excitation or ejection of the other K electron, and (b) for the total probability of electron ejection in orbital electron capture together with the ejected electron momentum spectrum. A discussion is given of the possibilities of experimental verification of the theory developed.

* Assisted by the joint program of the ONR and AEC.

Q7. An Upper Limit for Atomic Orbital Electron Ejection Accompanying K Capture in Fe^{55}. F. T. PORTER AND H. P. HOTZ, *Washington University.**—An upper limit has been determined for the number of atomic orbital electrons ejected during the decay of Fe^{55} by orbital capture. From cloud-chamber observations it is concluded that less than 0.6×10^{-6} electron are ejected per disintegration with energies in the range 30 kev to 205 kev. The theoretical prediction gives the order of 10^{-6} electron per disintegration for the frequency of the process in the energy range studied.

* Assisted by the joint program of the ONR and AEC.

Q8. Nuclear Spectra of Rb^{82} and Rb^{84}. CHARLES M. HUDDLESTON AND ALLAN C. G. MITCHELL, *Indiana University.**—The nuclear spectra of Rb^{82} (6.3 hr) and Rb^{84} (34 day) have been measured with a magnetic lens spectrometer. Rb^{82} emits two positron groups of energies 0.775 and 0.175 Mev. It also decays by orbital electron capture. A large number of gamma-rays accompanies the disintegration. Reasonable agreement with the gamma-rays emitted by Br^{82} has been obtained. Rb^{84} emits three groups of positrons having end-point energies of 1.629, 0.822, and 0.373 Mev. One gamma-ray whose energy is 0.890 Mev has been found. Level diagrams for these disintegrations will be discussed.

* Supported by the joint program of the ONR and AEC.

Q9. The Isomer Rb^{84m}. R. S. CAIRD AND ALLAN C. G. MITCHELL, *Indiana University.**—With the help of scintillation counters information on the isomer Rb^{84m} has been obtained. The isomer was produced by an $(n, 2n)$ bombardment of ordinary Rb salts. The half-life has been determined as 21 min. Three gamma-rays have been observed at 0.239, 0.463, and 0.890 Mev. The last gamma-ray occurs in the product Kr^{84}. Coincidence measurements show coincidences between the gamma-ray at 0.239 Mev and another of nearly the same energy, while coincidences between the 0.463 and the gamma-rays at 0.239 Mev are essentially negligible. A possible level scheme will be discussed.

* Supported by the joint program of the ONR and AEC.

Q10. The Disintegration of Sr^{91} and Y^{91m}.* D. P. AMES,† M. E. BUNKER, L. M. LANGER,‡ AND B. M. SORENSON, *Los Alamos Scientific Laboratory.*—The radiations from the fission product Sr^{91} (9.67 hr) have been studied using a magnetic lens spectrometer, a high resolution 180-degree focusing spectrometer, and a coincidence arrangement employing scintillation detectors. Five beta-ray groups are observed with end-point energies and relative intensities of 2.665 Mev, 26.1 percent; 2.03 Mev, 4.4 percent; 1.355 Mev, 29.3 percent; 1.093 Mev, 33.1 percent; and 0.62 Mev, 7.1 percent. The 2.665-Mev group has a forbidden shape indicating a spin change of two units and a parity change. Gamma-rays are found with energies of 1.413, 1.025, 0.747, 0.63, and 0.5512 Mev. The 0.5512-Mev gamma-ray has a $K/L+M$ internal conversion ratio of 6.00, which identifies it as an $M4$ isomeric transition. The isomeric state in Y^{91} has a half-life of 50.3 minutes and decays only by gamma-emission to the ground state. A disintegration scheme will be presented.

* Work performed under the auspices of the AEC.
† Now at the University of Kentucky, Lexington, Kentucky.
‡ Indiana University, Bloomington, Indiana.

Q11. Effect of the Chemical Binding and the Phase on Angular Correlations.* ROLF M. STEFFEN, *Purdue University.*—The influence of the chemical state and the phase of In compounds on the angular correlation of the Cd^{111} gamma-rays was investigated. It was found that the phase rather than the chemical structure of a particular In compound is responsible for the differences in the recovery time of the Cd atom, with the exception of the In metal, where the angular correlation depends on the size of the crystallites. Solid In compounds, i.e., dry $InCl_3$, InI_3, $In(NO_3)_3$, In_2O_3, $In(OH)_3$, $In_2(SO_4)_3$, In-8-hydroxyquinolinate, and also quenched In metal, show practically isotropic angular correlation. All liquid samples investigated, i.e., dilute aqueous solutions of $InCl_3$, InI_3, $In_2(SO_4)_3$, $In(NO_3)_3$, In-8-hydroxyquinolinate dissolved in $ChCl_3$, liquid InI_3 and $InCl_3$, and liquid In metal, exhibited the presumably maximum anisotropy $A=-0.19\pm0.02$. Electrodeposited In metal showed an anisotropy of -0.04 to -0.11 depending upon the size of the In crystallites. An attempt to influence the angular correlation of the Pt^{198} gamma-rays by using Au^{198} sources in different chemical states and environments (Au^{198} in Au, Au^{198} in Pt, dry $AuCl_3$, dilute aqueous solution of $AuCl_3$) failed. All Au^{198} sources showed the same angular correlation: $W(\vartheta)=1-1.20\ \cos^2\vartheta+1.12\ \cos^4\vartheta$; $(a_1=-1.20\pm0.05,\ a_2=+1.12\pm0.05,\ (a_1+a_2)=-0.08\pm0.03)$. This correlation is characteristic for a $2-Q+D-2-Q-0$ transition, with a 2.7 percent to 5.3 percent dipole admixture in the first transition.

* Supported by the AEC.

Q12. Isomerism for Cd^{117}, In^{117}, and In^{118}.* CHARLES D. CORYELL, PIERRE LÉVÊQUE,† AND HAROLD G. RICHTER,‡ *M.I.T.*—Radiochemical studies on cadmium isotopes formed in fission and their indium daughters, and the products of

Cd(n, γ) and Cd(d, p) reactions, show the known[1] 43d Cd^{115m}, and 2.3d $Cd^{115} \rightarrow$ 4.5h In^{115m}, and new evidence on the following species: 3.0h Cd^{117m}, decaying largely by I.T.; ~50m Cd^{117}, β^- and γ; 70m In^{117m} β^-, weak γ; ~2.5h In^{117} β^-, very weak γ; ~30m Cd^{115} β; and <1m In^{115}, 4 Mev β. The <1m In^{115} is isomeric with the known[2] 4.5m In^{115} not formed from Cd^{115}. Nishina[3] observed ~50m Cd in fission, assigned[1] to Cd^{111m}. Later workers[1] missed ~30m Cd^{115} and ~50m Cd^{117} by delay in studies. In recent spectrometric work[4] on supposed 1.95h In^{117}, ~2.5h In^{117} was masked by 4.5h In^{115m}. The ratio of 3.0h Cd^{117m} to ~50m Cd^{117} formed in the (d, p) reaction is near to secular equilibrium.

* This work was supported in part by the AEC.
† Research Fellow from the Commissariat à l'Energie Atomique (Paris) under M.I.T. Foreign Students Summer Project.
‡ Department of Chemistry, University of Oregon, Eugene, Oregon.
[1] C. D. Coryell and N. Sugarman, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), Appendix C.
[2] R. B. Duffield and L. M. Langer, Phys. Rev. **75**, 1967 (1949).
[3] Nishina, Yasaki, Kimura, and Ikawa, Phys. Rev. **58**, 660 (1940).
[4] J. D. Knight and G. A. Cowan, Los Alamos Scientific Laboratory, private communication

SATURDAY MORNING AT 10:00

Wilson Hall

(EUGENE FEENBERG presiding)

Invited Papers

R1. Photoproduction and Multiple Scattering of Mesons within Atomic Nuclei. K. M. WATSON, *Indiana University.* (30 min.)

R2. A New Theoretical Approach to the Pion-Nucleon Interaction. G. F. CHEW, *University of Illinois.* (30 min.)

R3. Charge-Independence in Meson Production. R. H. HILDEBRAND, *University of Chicago.* (30 min.)

R4. Neutron Binding-Energies of Heavy Elements and Some Applications. J. R. HUIZENGA, *Argonne National Laboratory.* (30 min.)

SATURDAY MORNING AT 10:00

Rebstock Hall

(R. D. SARD presiding)

Neutron Physics; General Nuclear Physics

S1. Neutron Resonances in Xenon. S. P. HARRIS, *Argonne National Laboratory.*—Previous measurements using scattering and boron absorption techniques indicated the existence of resonances in xenon at about 11 ev.[1] Using the high speed neutron velocity selector,[2,3] transmission measurements have been made on xenon gas in the 1.5 ev to a few thousand ev region. Two prominent resonances were found, at 13.9±0.2 and 9.3±0.2 ev, with a sample thickness of 0.260 g/cm^2. Calculation of $\sigma_0\Gamma^2$ by the method of Havens and Rainwater[4] for the 13.9-ev resonance gave $\sigma_0\Gamma^2 \sim 1000$ b (ev)^2. The observed cross section at the minimum of the transmission dip was >2000 b for this resonance with a resolution of about 1μ sec/meter. Transmission curves will be shown.

[1] S. P. Harris, Phys. Rev. **80**, 20 (1950).
[2] W. Selove, Rev. Sci. Instr. **23**, 350 (1952).
[3] Bollinger, Harris, and Schumann, Phys. Rev. **87**, 184 (1952).
[4] W. W. Havens, Jr., and L. J. Rainwater, Phys. Rev. **83**, 1123 (1951).

S2. Slow Neutron Resonances in Sm and Y.† V. L. SAILOR, H. L. FOOTE, JR., AND H. H. LANDON, *Brookhaven National Laboratory.*—The total neutron cross section of Sm and Yb[1] from 0.1 to ~40 ev has been measured with the Brookhaven crystal spectrometer. Resonances in Sm were observed at 0.094, 0.87, 3.43, 4.95, 8.20, 15, and 19 ev. The 0.094-ev resonance was previously reported by Borst[2] and Sturm,[3] and the resonance at 8.20 ev corresponds to the one previously observed by Sturm[3] at about 10 ev. The 8.20-ev resonance is exceptionally strong and, in fact, closely approaches the limiting value $\sigma_0 \approx \pi\lambda_0^2$, which is consistent with the results of Goldhaber.[4] The isotopic assignment of the Sm resonances obtained by using enriched isotopes will be discussed. Resonances in Yb occur at 0.597, 4.55, 8.09, 13.3, 18.2, and ~30 ev.

† Research performed under the auspices of the AEC.
[1] Exceptionally pure samples of Sm and Yb were generously lent to us by Dr. F. H. Spedding of the Ames Laboratory, AEC.
[2] Borst, Ulrich, Osborne, and Hasbrouck, Phys. Rev. **70**, 557 (1946).
[3] W. J. Sturm, Phys. Rev. **71**, 757 (1947).
[4] Goldhaber, Lowry, and Sunyar, Brookhaven National Laboratory Report BNL-C-9, 96 (1949).

S3. Total Cross Sections for Fast Neutrons.* R. L. BECKER,† M. WALT,‡ AND A. OKAZAKI, *University of Wisconsin.*—The total neutron cross sections of Co, Ga, Se, Cd, Te, Pt, Au, Hg, and Th were measured as a function of neutron energy, from 0.1 to 3 Mev. Transmission experiments were performed using cylindrical samples of the elements. For energies above 1 Mev, neutrons were produced by bombarding a Zr−H^3 target with protons. Below 1 Mev, a lithium target was used. To determine the correction for neutrons scattered into the detector by the sample, the variation of the apparent cross section with diameter of the sample was investigated. Previous data had shown regularities in total fast neutron cross sections,[1] and the present experiment was performed to supplement these data. The results give additional evidence that, aside from resonance structure, curves of total neutron cross

sections *versus* energy have characteristic shapes which vary slowly with atomic weight.

* Work supported by the Wisconsin Alumni Research Foundation and the AEC.
† National Science Foundation Predoctoral Fellow.
‡ AEC Predoctoral Fellow.
[1] H. H. Barschall, Phys. Rev. **86**, 431 (1952).

S4. Gamma-Rays Produced by the Inelastic Scattering of 14-Mev Neutrons.* LEWIS C. THOMPSON, *The Rice Institute* (introduced by J. G. Risser).—A NaI scintillation spectrometer has been used to detect the gamma-rays produced by the inelastic scattering 14-Mev neutrons. Positive results were obtained in the case of iron and lead. In iron, lines were seen corresponding to the 0.845- and 1.24-Mev gamma-rays reported by Elliott and Deutsch[1] from the excited state of Fe^{56}. Above this energy the spectrum appeared to be a continuum which extended to about 8 Mev. The lead spectrum seemed to be a continuum that extended to 3 Mev. This was interpreted to mean that the $(n, 2n\gamma)$ reaction probably predominated in lead, but that the $(n, n\gamma)$ reaction was occurring at least part of the time in iron. The NaI itself showed a possible capture gamma-ray at 5.8 Mev. Its spectrum extended up to 14 Mev.

* Work performed under the auspices of the AEC.
[1] L. G. Elliott and M. Deutsch, Phys. Rev. **63**, 321 (1943).

S5. Measurement of the Energy of Isotropic Fast Neutrons with Li^6 Loaded Emulsions.* J. H. ROBERTS, W. O. SOLANO, D. E. WOOD, AND H. B. BILLINGTON, *Northwestern University*.—One-hundred micron *E*1 and *C*2 Ilford plates loaded with enriched Li^6 were exposed to neutrons produced in electrostatic generators from $I_1i^7(p, n)Be^7$ and from $H^3(p, n)Ne^3$. The plates, wrapped in cadmium, were rotated so as to mock-up a condition of isotropic neutron incidence. The plates were faded and developed so as to obtain good discrimination in triton-alpha tracks resulting from $Li^6(n, \alpha)H^3$. Neutron energies from the Be^7 ground-state transition were 0.200, 0.600, 1.00, and 1.500 Mev from the $p-t$ reaction. Target thicknesses were usually 25 kev. The plates were treated with glycerine to prevent shrinkage. Measurements of the triton length, alpha-length, and triton-alpha angle gave information to select tracks "favoring"[1] the triton to obtain optimum energy resolution. Peaks having widths from 100 to 300 kev at half-maximum were obtained, depending upon neutron energy and selection criteria. Observer agreement with generally good, but some bad results were obtained. Methods of putting the technique on a more objective basis are being investigated.

* Work supported by an AEC contract.
[1] G. R. Keepin and J. H. Roberts, Rev. Sci. Instr. **21**, 163 (1950).

S6. The Production of Characteristic X-Rays by Proton Bombardment.* B. E. SIMMONS,† H. W. LEWIS, AND E. MERZBACHER,‡ *Duke University*.—Characteristic x-rays produced by 2- to 3-Mev protons on thick targets of Mo, Ag, Ta, Au, and Pb have been investigated with a NaI scintillator. The x-ray energies are such that the *K* series could be studied for the two lightest elements and both *K* and *L* series for the three heavy ones. Lines in the same series could not be resolved, but *K* and *L* series for a given element gave well-separated differential pulse-height peaks. No x-ray continuum is produced by proton bombardment and individual characteristic photons lose their entire energy in the scintillator. Thus, the width of the counting rate peak is due partly to the presence of several lines in a series and partly to crystal and phototube resolution. Variation of the cross section for *K* ionization as a function of target *Z* and proton energy, together with measured absolute cross sections, will be discussed in relation to the theory of Henneberg and to the experimental results of previous workers using ionization chambers and absorbers. Thick target yields were converted to cross sections by numerical integration assuming the fourth power dependence of proton energy derived by Henneberg. The correction for Auger electron emission is less than a factor of two for the lightest element. Results are important in the theory of stopping power for heavy particles.

* This work was supported by the AEC.
† Now at the University of Minnesota.
‡ Now at the University of North Carolina.

S7. X-Rays from the Mesic Carbon Atom.* H. J. SCHULTE, J. B. PLATT, AND M. CAMAC, *University of Rochester*.—We have observed 100-kev quanta in coincidence with the stopping of negative pions in carbon.[1] These quanta are of the correct energy to arise from x-ray transitions of the pion to the *K* shell of the mesic carbon atom. To evaluate the yield of such *K* x-rays we have done the following: (a) measured the spatial distribution and absolute number of pions stopped in the carbon; (b) identified and counted the x-rays by means of a NaI scintillation spectrometer; and (c) calculated the over-all detection efficiency including average solid angle, x-ray filter attenuation and crystal efficiency for the expected energy. The x-ray energies have been measured by two independent methods: (a) the balanced filter method of Ross with x-ray absorbers of Pb and Th; (b) use of an artificial light pulse[1] which had previously been matched to 74-kev NaI response. Our present value for the yield of *K* x-rays from carbon is 0.12 ± 0.02 x-rays per stopped pion.

* Supported jointly by the University of Rochester and the AEC.
[1] Camac, McGuire, Platt, and Schulte, Phys. Rev. **88**, 134 (1952).

S8. *Z* Dependence of Mesic X-Ray Yield.* M. CAMAC, J. B. PLATT, AND H. J. SCHULTE, *University of Rochester*.—Using the experimental arrangement described in the previous paper, x-rays have been observed in coincidence with the stopping of negative pions in Be and H_2O. The energies of these x-rays are in agreement, within experimental error, with the Moseley law predictions for the mesic Be and O atoms. In the case of O the yield of these quanta has been found to be 0.21 ± 0.07 quanta per stopped pion. It is expected that results will also be presented for mesic N and F atoms as well. Simple theoretical arguments[1] indicate that this yield *Y* should be given by $Y=1/(1+CZ^3)$, where *Z* is the atomic number and *C* is a constant of the order of 0.2. Preliminary work has shown that this formula predicts correctly the yield for the C mesic atom, but the predicted value of 0.06 for O is substantially lower than the observed value. The implications of this disagreement will be discussed.

* Supported jointly by the University of Rochester and the AEC.
[1] A. M. L. Messiah and R. E. Marshak, NYO-3701; Phys. Rev. (to be published).

S9. The Excited Energy Levels of Nuclei as Rational Multiples of the Electron Mass. ENOS E. WITMER, *University of Pennsylvania*.—The writer[1] has recently presented evidence which indicates that the rest mass *m* of the negative electron is the natural unit of mass for nuclei and elementary particles. The mass of any nucleus or elementary particle in any state may be written *Mm*. Then we believe *M* is always a rational number. Consequently, the excited energy levels of nuclei may also be written as *Mm*, because the difference of two rational numbers is another rational number. Now this conclusion can be tested rather precisely in a number of cases. Out of 122 excited energy levels measured with sufficient accuracy for this purpose there were 13 for which *M* was an integer to within ±0.02. The probability of this occurring by chance is only 8.7×10^{-4}. Also in the same set of energy levels there were 44 for which *q* was 1, 2, 3, or 4, where $M=p/q$, both *p* and *q* being integers. Again the tolerance was ±0.02. The probability of this occurring by chance is only 9.2×10^{-4}. In the case of one nucleus there were 3 integral values of *M* in 20 energy levels.

[1] Enos E. Witmer, Phys. Rev. **87**, 237 (1952).

SATURDAY MORNING AT 10:00

Crow Hall, 101

(C. F. SQUIRE presiding)

Fluid Dynamics; Cryogenics

T1. On the Fundamentals of the Boundary Layer Theory. M. Z. v. KRZYWOBLOCKI, *University of Illinois* (introduced by F. T. Rogers, Jr.).—The author discusses two fundamental problems in the boundary layer theory, namely, (a) the proof of existence and uniqueness of the solution of the equations governing the motion and energy distribution in the boundary layer and (b) the fundamental differential system of equations governing the distribution of the velocity, density, pressure, and temperature in the boundary layer. A brief discussion on the subject of fundamentals of the boundary layer in hypersonic flow closes the paper.

T2. Streaming Potentials Developed across Porous Diaphragms for Sinusoidal Flow.* R. G. PACKARD, *Baylor University* (introduced by H. D. Schwetman).—Sinusoidal streaming potentials are developed across porous diaphragms of sand, plastic shavings, cellulose, and fritted glass for sinusoidal pressures. The frequency range studied was 20 cps to 350 cps, and the pressure amplitudes ranged from 0 to 20,000 dynes/cm². Distilled water was used throughout the experiments. A specially designed plastic cell in which the samples were retained is described. Frequency response curves and amplitude response curves are given.

* Work done under contract between Defense Reserve Laboratory, the University of Texas, and the U. S. Navy.

T3. Ultrasonic Velocity, Density, and Compressibility of Supercooled H_2O and D_2O. R. T. LAGEMANN AND L. W. GILLEY, *Vanderbilt University*.—Because water can be easily supercooled, it has been possible to measure the velocity of compressional waves in liquid water (H_2O and D_2O) over a range of temperatures extending to some six degrees below the nominal freezing point, using a fixed-frequency (500 kc), variable-path sonic interferometer. It was also possible to determine the density of heavy water in the supercooled state and obtain values of the adiabatic compressibility. The curves representing the variation of density with temperature are symmetrical and congruent for the two isotopic liquids. It is confirmed that the compressibility of D_2O is greater than that of ordinary water, compared either at the same temperature or in corresponding states based on the freezing points. The new measurements on the three properties yield values which fall on smooth extrapolations of the previously known data, indicating that there is not partial ordering of the liquid structure into the solid structure at temperatures below the nominal freezing point, at least none at times removed from the start of observed freezing.

T4. Propagation of Explosive Produced Air Shocks. J. SAVITT, *U. S. Naval Ordnance Laboratory*.—It has been previously reported* that the velocities of ionized air shocks produced by the detonation of highly confined solid explosives depend upon the distance from the explosive air interface, the composition of the explosive, its weight, its geometry, and to some extent for a particular explosive upon its loading density and particle size. These small scale one-dimensional ionized air shock propagation experiments near detonating explosives have been extended to include measurements made in heavy walled tubes varying in internal diameter from 0.100 to 0.300 inch. The velocities of one-dimensional air shocks produced by detonating highly confined TNT and RDX were measured at several distances from the explosive air interface. These velocities were found to depend upon the diameter of the explosive as well as upon the diameter of the shock tube. It was found, in general, that for a fixed shock tube diameter the air shock velocity increased with increasing explosive diameter, while for a fixed explosive diameter it was observed that the air shock velocity increased with decreasing shock tube diameter.

* J. Savitt and R. H. Stresau, Phys. Rev. **85**, 732(A) (1952).

T5. Plane Supersonic Flow Patterns in Ionized Media. W. R. ATKINSON AND R. G. FOWLER, *University of Oklahoma*.—Expansion of spark discharges at low pressure when confined to a cylindrical glass tube can result in plane supersonic flow accompanied by all the normal behavior of such a flow. Shocks and contact surfaces can be observed in their own luminosity, and interactions of these fronts with each other furnish considerable evidence for the supersonic flow interpretation of the Rayleigh phenomenon. Most of the variety of interactions which can be produced are also excellent exemplifications of the theory of plane supersonic flow and will be discussed. New interactions have been observed, however, which are not recognized by this theory and which may reflect the peculiar processes of the highly ionized plasma.

T6. Ion Concentrations in Shock-Type Spark Discharge Tubes. R. G. FOWLER AND H. C. ROSE, *University of Oklahoma*.—Measurements of time-averaged ion concentration at all points along a shock type discharge tube existing as a result of the expansion of gas excited during the discharge of capacitor have shown behavior which can only be accounted for by assuming either that the Holtsmark theory of Stark broadening cannot be applied to this situation, or that excitation continues actively after the cessation of the discharge current. The ion concentration indicated by the Holtsmark theory reaches a maximum during the expansion, and the total intensity of the discharge is a maximum at the same point. The behavior of the post discharge expansion is insensitive to the direction of the original discharge current, so that it is probable that electrical mechanisms are secondary to thermal ones in causing the expansion.

T7. Flow of Helium II through Narrow Slits. RICHARD T. SWIM,* *The Rice Institute*.—Experiments are in progress to measure the volume rate of flow of helium II, under pressure gradients, through slits of width 3.5μ or less. The experimental arrangement is similar to that of Bowers and Mendelssohn[1]; however, the apparatus is such that considerably higher pressure heads can be realized than in previous work of this nature. The measured flow rates at pressure heads of less than 4 cm of helium are in general agreement with the results of other investigators,[1,2] but at higher pressures (extending thus far to 14 cm of helium) the flow rates are no longer adequately described as proportional to a power of the pressure head. In fact, the rate appears to approach a value independent of pressure at the highest pressure heads, the maximum linear velocity being of the order of 30 cm/sec at a temperature of 1.75°K.

* Magnolia Petroleum Company Fellow.

[1] R. Bowers and K. Mendelssohn, Proc. Roy. Soc. (London) **A213**, 158 (1952).

[2] G. K. White, Proc. Phys. Soc. (London) **A64**, 554 (1951).

T8. Frozen Moments in a Superconducting Sphere. TOM S. TEASDALE, *The Rice Institute.*—A series of experiments is being carried out in which the residual magnetic flux of a superconductor is measured. The apparatus consists of a torsion pendulum with which the torque on a superconducting tin sphere is measured as a function of an externally applied magnetic field. If an effective magnetic moment for the sphere is defined by considering the sphere as a magnetic dipole oscillating in a uniform field, then it is found that the moment frozen in at constant temperature is a reproducible function of the critical field for the temperature at which the moment is formed. Preliminary investigations indicate that the moment, when measured at the temperature at which it is formed and calculated using the model indicated above, shows a pronounced minimum when plotted as a function of the critical field at which it is formed. (The moment appears to become large as the zero field transition temperature is approached and as one goes to very low temperatures.)

T9. Current Noise in Partially Superconducting Resistors at Temperatures Down to 2°K. B. KAPLAN AND J. G. DAUNT, *Ohio State University.*—Measurements have been made of the current noise in tantalum and leaded phosphor-bronze in the helium temperature region, the noise power being obtained as a function of the frequency of observation from 200 to 4000 cycles/sec. In the intermediate state the tantalum specimen showed large current noise. A possible explanation is put forward on the basis of temperature fluctuations in the specimen. No current noise was observed in the partially superconducting leaded phosphor-bronze specimen.

SATURDAY AFTERNOON AT 2:00

Loudermann Hall

(J. S. JASTRAM presiding)

Beta-Emitters from Caesium Onward; Nuclear Scattering

V1. Gamma-Radiation from Radioactive Cesium 134.* J. M. LEBLANC, W. H. NESTER, D. W. MARTIN, M. K. BRICE, AND J. M. CORK, *University of Michigan.*—Using photographic magnetic spectrometers the energies of conversion and photoelectrons from specimens of cesium, obtained as a fission product, have been evaluated. The results indicate some needed revision in the previously reported values for seven of the gamma-rays and show the presence of four additional gammas not before observed. The energies of these radiations, believed to be accurate to ±0.2 percent, are 202.5 475.0, 563.0, 569.7, 605.4, 662.7, 796.8, 802.6, 1039, 1168, and 1368 kev. The K/L ratio for the 605.4- and the 796.8-kev gamma-rays are found to be 6.4±0.8 and 7.3±0.8, respectively, and both transitions are believed to be electric quadrupole. From mathematical identities evident in combinations of the gamma-energies it seems quite likely that at least ten of the transitions are associated with beta-emission and not K capture.

* This project received the joint support of the AEC and the ONR.

V2. Radioactivity of Cesium 138.* L. M. LANGER, *Indiana University,* R. B. DUFFIELD, *University of Illinois,* AND C. W. STANLEY, *Los Alamos Scientific Laboratory.*—Cs^{138} was chemically separated from other activities after a delayed collection of gaseous fission products from the "water boiler." Beta- and gamma-activities were found to decay with a single period of 32.0 minutes. The beta-spectrum was studied in a magnetic lens spectrometer. The resulting Fermi plot is concave towards the energy axis with a maximum energy of 3.40 Mev. An internal conversion line corresponding to a 0.463-Mev gamma-ray was also observed. In a ten-channel scintillation spectrometer, gamma-rays of 0.46, 0.98, and 1.44 Mev were observed with relative intensities of 0.33, 0.43, and 1.00, respectively. Beta-gamma coincidence absorption measurements indicate that betas as high as about 3 Mev are followed by one of the harder gamma-rays, probably the 1.44 Mev. Gated gamma-gamma coincidences further suggest that the 1.44-Mev gamma is, surprisingly, in series rather than in parallel with the 0.46- and 0.98-Mev gamma rays. It appears likely then that the 3.40-Mev beta-transition is not to the ground state of Ba^{138} but rather is followed by the 1.44-Mev gamma for a total energy release of 4.8 Mev, in good agreement with the predicted mass difference. It appears somewhat doubtful that the ground state of Cs^{138} has zero spin as suggested by the $(g_{7/2}, f_{7/2})$ assignment of the shell model.

* Research carried out at the Los Alamos Scientific Laboratory of the University of California under contract with the AEC.

V3. The Disintegration of Re^{188m}. J. W. MIHELICH, *Brookhaven National Laboratory.**—Neutron irradiation of Re^{187} produces a 22-minute activity of Re^{188m} which is isomeric with the 16.9-hr ground state. A NaI scintillation spectrometer reveals photopeaks corresponding to photons of ~60 kev and 105 kev. The number of quanta in the "60"-kev peak, consisting of Re $K-X$-rays and 63.5 γ-rays, is at least 10 times as great as the number in the 105-kev peak. The intensity of these photons, as well as that of $L-X$-rays observed with a proportional counter and the photon-photon coincidence rate, decays with a 22-minute half-life. The conversion electron spectrum was investigated with permanent magnet spectrographs. The energies of the conversion lines correspond to atomic electrons ejected by two transitions in Re: 105 kev (K, L_I, M_I) and 63.5 kev (L_I, M_I, N). The 22-minute lifetime cannot yet be definitely ascribed to either transition. Energy-lifetime considerations indicate a transition involving a spin change of 3.

* Research carried out under contract with the AEC.

V4. Isomeric Pt^{193}.* J. B. SWAN, W. M. PORTNOY, AND R. D. HILL, *University of Illinois.*—Iridium was bombarded with 12-Mev deuterons, and the platinum fraction containing radioactive Pt^{191} and Pt^{193} was chemically separated from the target material. The conversion-electron spectrum of the platinum was investigated, using 180° spectrographs. Among a large number of lines present were those of a strong 135-kev transition in platinum, decaying with a half-life ~4 days, and those of 83-, 96-, and 173-kev transitions, probably in iridium, decaying with a half-life ~3 days. The measured K/L ratio of 0.275, the $L_I{:}L_{II}{:}L_{III}$ ratios of 1:0:2, and the half-life ~4 days, identify the 135-kev transition as $M4$. Platinum was irradiated with γ-rays from a 22-Mev betatron, and strong lines from the 135-kev transition were observed. This $M4$ isomeric transition is, therefore, in Pt^{193}. The 83-, 96-, and 173-kev transition lines were not observed and are attributed to Pt^{191}. Other transitions of 130 and 76 kev, arising

from Pt^{195m} and Pt^{197}, respectively, were also observed. Neither source gave evidence of the 129- and 42-kev transitions which might be expected to occur following K capture in Pt^{191}.

* Assisted by the joint programs of the AEC and ONR.

V5. Neutron Deficient Isotopes of Hg.† K. GOPALAKRISHNAN AND A. DE-SHALIT, *Princeton University*, AND J. W. MIHELICH, *Brookhaven National Laboratory*.—A study of Hg^{195} and Hg^{193} was undertaken in order to look for a possible "family" of similar decay schemes. The isotopes were prepared by bombarding an Au target with high energy protons (we are indebted to Dr. S. Goldhaber, Dr. W. F. Goodell, and Dr. D. H. Greenberg of Columbia University, New York, for their kind cooperation in carrying out these irradiations at the Nevis Cyclotron Laboratory). The Hg was then separated carrier free and studied in a high resolution double focusing spectrometer at the Palmer Laboratory and in the permanent magnet spectrograph at Brookhaven National Laboratory. An isomeric state in Hg^{195} (38 hr) decays via two gammas (123 and 37 kev) to the ground state of Hg^{195} and also by a K capture to an isomeric state in Au^{195} which decays via two gammas (57 and 262) to the ground state of Au^{195}. The situation in Hg^{193} is similar, the respective gammas being 102 and 39 in Hg (10 hr), 32, 258, and 120 in Au. The half-life of Hg^{193} in the ground state is 27 hr.

† Work supported by the AEC and Higgins Scientific Trust Fund.

V6. Effects of Radioactive Disintegrations on Inner Electrons of the Atom. J. S. LEVINGER, *Louisiana State University*.—The probability that nuclear emission of an alpha-particle causes ionization of a K or L electron of the atom is calculated by time dependent perturbation theory, using Coulomb wave functions. Due to the nuclear recoil, Migdal's results[1] for dipole transitions are multiplied by $(A-2Z)^2/(A-4)^2$, roughly 1/25. Quadrupole transitions are negligible for K electrons, but are the predominant cause of ionization of L electrons. The ionization probabilities per alpha for Po^{210} are 10^{-7} for the K shell and 10^{-4} for the L shell. Relativistic corrections and screening corrections would increase the ionization probability by a factor of about 2 for the K shell and at least 3 for the L shell. This estimate is based on our calculation of the relativistic and screening corrections to the calculation[1] of ionization probability following beta-decay. We will compare our results with recent experiments on characteristic x-rays associated with Po^{210} and with RaE.

[1] A. Migdal, J. Phys. U.S.S.R. **4**, 449 (1941).

V7. A Precise Measurement of the "*F*" Line of Thorium B. D. I. MEYER* AND F. H. SCHMIDT, *University of Washington*.—The internal conversion electrons resulting from the decay of Th B are widely used as calibration standards in beta-ray spectroscopy. Siegbahn, Craig, Lindström,[1] and others have determined the $H\rho$ values of several lines. Lindström's most straightforward method involved the direct measurement of H (in terms of the proton magnetic moment) and of ρ. We have measured the momentum and energy of the "F" line by comparison with electrons accelerated through a measured potential difference. The comparison was made in an iron free high resolution (0.13 percent) solenoid spectrometer. Both components of the earth's field were canceled out. The accelerating potential was measured by a "series-parallel" precision manganin resistor which permitted direct comparison with standard cells. Corrections for the work function of the Wolfram filament of the electron gun were applied. Accelerating potentials up to 20 kv were used corresponding to a momentum of about one-third that of the "F" line. Linearity of the spectrometer was checked over the full range (2–20 kev) of the electron gun and, using published values of electron lines, at intervals up to 2.6 Mev. Our result for the "F" line is 1388.56 ± 0.21 gauss cm, in agreement with Lindström's value.

* Now at the University of Oklahoma.
[1] G. Lindström, Phys. Rev. **83**, 465 (1951).

V8. Proton-Proton Scattering at 5.77 Mev Using Photographic Techniques.* R. O. KERMAN,† W. E. KREGER,‡ AND P. G. KRUGER, *University of Illinois*.—Zimmerman and Kruger's[1] $p-p$ scattering results at 5.86 Mev gave a P-wave phase shift of $-0.36°\pm0.22°$; Rouvina[2] found no p-wave phase shift at 3.4, 6.8, and 7.5 Mev. To check this difference in results, new data have been taken at 5.77 Mev using a modification of the scattering chamber used previously by Rodgers *et al.*[3] The following absolute differential $p-p$ scattering cross sections in millibarns per steradian in the center-of-mass system were obtained (errors are probable errors): 23.00°: 118.0±0.8, 23.87°: 110.0±0.90, 26.00°: 95.91±0.70, 27.85°: 91.73±0.79, 30.00°: 87.30±0.64, 31.84°: 83.53±0.73, 35.00°: 81.98±0.58, 40.00°: 82.82±0.60, 45.00°: 81.12±0.67, 50.00°: 83.28±0.64, 54.76°: 85.00±0.62, 60.00°: 85.70±0.65, 69.70°: 86.86±0.71, 79.68°: 86.73±0.70, 84.73°: 86.51±0.72, 89.68°: 87.18±0.70, 94.71°: 87.28±0.68, 99.68°: 87.87±0.70, 109.69°: 86.01±0.69. These gave an S-wave phase shift of $54.96°\pm0.16°$ and a P-wave phase shift of $-0.08°\pm0.05°$.

* This work has been supported jointly by the ONR and AEC and by a grant from the Research Corporation.
† Now at Kalamazoo College, Kalamazoo, Michigan.
‡ Present address: Code 3941A, U.S.N. Radiological Defense Laboratory, San Francisco 24, California.
[1] E. J. Zimmerman and P. G. Kruger, Phys. Rev. **83**, 218 (1951).
[2] J. Rouvina, Phys. Rev. **81**, 593 (1951).
[3] Rodgers, Leiter, and Kruger, Phys. Rev. **78**, 656 (1950).

V9. Inelastic Scattering of Neutrons. ROBERT B. DAY, *Los Alamos Scientific Laboratory*.—The inelastic scattering of neutrons has been investigated by observing the gamma-rays emitted in the decay of the excited nuclei. The detector was a NaI(Tl) scintillation counter shielded from the neutron source by a tungsten alloy cone and surrounded by a scattering ring of the material to be investigated. By observing the pulse-height spectrum from the scintillation counter it was possible to distinguish the gamma-rays from the scattering ring from the neutron-induced background, and at the same time to measure their energy to an accuracy of 1–2 percent. With a monoenergetic source of 2.5-Mev neutrons the following gamma-rays have been found (energies in Mev): B^{10}: 0.478, 0.717; F^{19}: 0.084, 0.114, 0.199, 1.36; Mg: 1.365; Al^{27}: 0.843, 1.018, 2.20; S: 0.077, 2.23; Fe: 0.850, 1.25, 1.42. With 5.5-Mev neutrons a 4.45-Mev gamma-ray has been found in carbon. These gamma-rays correspond in general to transitions between known levels of the target nuclei. Experiments have shown that the effects due to the cone are negligible except as a shield for the detector. Further work is in progress to measure the cross sections for these reactions.

V10. The Total Neutron-Proton Scattering Cross Section at 2.5 Mev.* R. E. FIELDS, R. L. BECKER,† AND R. K. ADAIR, *University of Wisconsin*.—The total cross section of hydrogen for 2.5-Mev neutrons has been determined by measuring the transmission of samples of 2-2-4 trimethylpentane and graphite. The neutrons were produced by bombarding thin targets of tritium absorbed in zirconium with protons from the electrostatic generator. Proton energy was measured with an electrostatic analyzer. A narrow neutron scattering resonance in carbon at 2078.5-kev neutron energy (measured by comparison with the $Li^7(p, n)Be^7$ threshold) was used as a calibration point. A one-inch diameter hydrogen recoil counter filled to a pressure of 500 pounds per square inch and placed 20 in. from the neutron source, at 0° relative to the proton beam, served as neutron detector. The discriminator was biased to reject pulses from neutrons of less than 1.25-Mev energy, thus reducing the background to about 0.6 percent. The preliminary results of this measurement are $\sigma=2.525\ (\pm0.009)\times10^{-24}$ cm²

at neutron energy 2.532 (±0.006) Mev. These values together with the values of A_T, A_S, and r_t given by Burgy, Ringo, and Hughes[1] yield a singlet effective range of 2.59 (±0.20)×10^{-13} cm which is not in disagreement with the hypothesis of charge independence of nuclear forces.

* Work supported by the Wisconsin Alumni Research Foundation and AEC.
† National Science Foundation Predoctoral Fellow.
[1] Burgy, Ringo, and Hughes, Phys. Rev. **84**, 1160 (1951).

V11. The Elastic Scattering of Alpha-Particles by O^{16}.† JOHN R. CAMERON,* ROBERT H. DAVIS, AJAY S. DIVATIA, FREDERIC J. EPPLING, AND RICHARD W. HILL, *University of Wisconsin.*—The differential cross section for elastic scattering of alpha-particles by O^{16} was measured in a gas scattering chamber using alpha-particles accelerated in the Wisconsin electrostatic generator. Alpha-particle energies used were between 0.94 and 4.0 Mev. Cross sections were measured at θ(c.m.) = 168.0°; 140.1°; 124.6°; and 90.0°. Because both particles have zero spin, each partial wave except $l=0$ has a zero amplitude at some angular position. The P-wave is zero at 90.0°; the D-wave is zero near 124.6°; and the F-wave is zero at 90.0° and near 140.1°. This permitted the unambiguous assignment of J-values to the resonances from a qualitative observation of the cross section. The resonances were analyzed using the Wigner-Eisenbud one-level approximation to determine the width and resonant energy of each resonance. Five scattering anomalies were observed to which the J-values and resonant energies using the Ne^{20} ground state as the energy zero are the following: S at 6.738 Mev; F at 7.182 Mev; S at 7.218 Mev; D at 7.450 Mev; and D at 7.854 Mev. The parity is odd for odd J and even for even J. The uncertainty in these energies is about 10 kev.

* Work supported by the Wisconsin Alumni Research Foundation and AEC.
† AEC Predoctoral Fellow.

V12. Inelastic Nuclear Scattering of Photons by Rh^{103}.* C. S. DEL RÍO† AND V. L. TELEGDI, *University of Chicago.*—A lower limit to the cross section for inelastic nuclear scattering of photons $\sigma(\gamma, \gamma')$ can be determined by irradiating an element having an isomeric state in its neutron richest isotope with high energy photons and measuring the isomeric activity. Rhodium foils were exposed to the Chicago betatron and the yield of Rh$^{103}(\gamma, \gamma')$Rh^{103*} was measured as a function of energy. Activities were counted with a windowless 4π-proportional counter and Ta$^{181}(\gamma, n)$Ta^{180} was used as a monitor above 8 Mev, adopting the improved results of the Saskatchewan group. It was ascertained that the fast neutron contamination of the betatron beam contributed but a small fraction of the Rh^{103*} activity. The cross section is found to go through a peak of the order of 10 mb at about 12.5 Mev and to be appreciable below the Rh$^{103}(\gamma, n)$ threshold, reported at 9.35 Mev. The observed location of the peak is considerably lower than would be expected for Rh$^{103}(\gamma, n)$ from the empirical A-dependence of (γ, n) cross sections and the case of Au$^{197}(\gamma, \gamma')$Au^{197*}, but is theoretically not unreasonable. Similar studies on other elements are in progress.

* Assisted by the joint program of the AEC and ONR.
† From Junta de Energía Nuclear, Madrid.

V13. Multiple Scattering Effects in Pion-Deuteron Scattering. K. A. BRUECKNER, *Indiana University.*—The scattering of pions by deuterons has been considered in the "impulse approximation" in which the motion of the nucleons is neglected during the scattering process. It is then possible to obtain an exact solution to the multiple scattering problem if scatterings which do not conserve energy are neglected. The effects of charge exchange are included, but the scattering has been assumed to be restricted to P-states and to be spin independent. It is found that the scattering is strongly depressed when the nucleons are within a distance roughly equal to the geometric mean of the pion scattering amplitudes from neutron and proton. These results are applied to a consideration of high energy pion scattering, making use of the results of Fermi[1] for the scattering amplitudes. A sizeable depression of the total cross sections relative to the free particle cross sections is found. This is in contrast to the predictions of the theory neglecting multiple scattering which gives a large positive interference effect. A comparison with experiment will be made.

[1] Fermi, Anderson, and Nagle (private communication).

SATURDAY AFTERNOON AT 2:00

Rebstock Hall

(H. L. ANDERSON presiding)

Invited Papers in Nuclear Physics

W1. Recent Research on Mu-Mesons. R. D. SARD, *Washington University.* (30 min.)

W2. Level Classification by Resonance Scattering of Protons and Alphas. H. T. RICHARDS, *University of Wisconsin.* (30 min.)

W3. Atomic Masses of the Light Elements. T. L. COLLINS, *University of Minnesota.* (30 min.)

W4. Coincidence Measurements with Beta-Ray Spectrometers. ERLING JENSEN, *Iowa State College.* (30 min.)

SATURDAY AFTERNOON AT 2:00

Brown Hall

(A. H. WEBER presiding)

Invited Paper

X1. Galvanomagnetic Effects in Semiconductors. VIVIAN A. JOHNSON, *Purdue University.* (30 min.)

Solid-State Physics. II

X2. Energy Loss of Medium-Fast Electrons in Metals.* E. M. BARODY, *Battelle Memorial Institute.*—It has been considered probable that excitation of valence electrons to the next Brillouin zone makes an important contribution to the energy loss in metals of electrons with energy in the range 10^2 to 10^3 ev. According to Wooldridge[1] and Vyatskin,[2] the matrix element for excitations of this type varies inversely as the square of the momentum change of the primary, and the corresponding energy loss per unit primary path is approximately independent of the energy. In the work to be reported, the matrix element is treated by a method somewhat different from that used by Wooldridge and is found to vary more nearly as the inverse *first* power of the momentum change of the primary. This result implies a rate of energy loss which is inversely proportional to the energy and suggests an energy loss curve similar to that for free atoms. Reasons for the discrepancy and the significance of the present result for secondary emission will be discussed.

* Sponsored by the Army Signal Corps and the Air Force.
[1] D. E. Wooldridge, Phys. Rev. **56**, 562 (1939).
[2] A. Ya. Vyatskin, J. Exptl. Theoret. Phys. (U.S.S.R.) **20**, 557 (1950).

X3. On the Transmission of Electrons through Thin Metallic Foils. C. H. CHANG, C. S. COOK, AND H. PRIMAKOFF, *Washington University.**—Experimental studies have been made on the relative transmission of positrons and negatrons through aluminum and platinum windows of an end-window type G-M counter. In qualitative agreement with the theoretical predictions that more scattering takes place in material having higher atomic number, a platinum foil having the same surface density as a corresponding aluminum foil shows lower relative transmission at any given energy, even though the low-energy cutoffs of the two windows are just about the same. Also in qualitative agreement with theory a larger percentage of positrons than negatrons are transmitted at any given energy for the same foil. Theoretical transmission curves, with empirically determined constants, have been developed. These curves are in relatively good agreement with the experimental curves.

* Assisted by the joint program of the ONR and AEC.

X4. The Magnetic Structure of Manganese Antimonide. N. S. GINGRICH,* C. G. SHULL, AND M. K. WILKINSON, *Oak Ridge National Laboratory.*—Neutron diffraction data have been obtained for a polycrystalline sample of Mn_2Sb at a series of temperatures ranging from 77°K to 940°K in order to determine the strength and relative orientation of the atomic magnetic moments which are responsible for the observed ferromagnetism of this compound. The room temperature observations (well below the Curie temperature of 275°C) agree reasonably well with Guillaud's model,[1] in which half of the Mn atoms have magnetic moments of three Bohr magnetons parallel to each other and the other half are of five Bohr magnetons directed antiparallel to the first group. At high temperatures above the Curie temperature, however, the observed paramagnetic scattering is only about half that which is calculated for this model. The moments are found to be parallel to the C_0 axis of the tetragonal cell at room temperature and to rotate into the basal plane at low temperature as Guillaud's magnetic measurements have indicated.

* On leave from the University of Missouri during part of 1952.
[1] C. Guillaud, J. phys. et radium **12**, 492 (1951).

X5. Magnetic Inelastic Scattering of Neutrons in Fe. H. PALEVSKY, R. S. CARTER, AND D. J. HUGHES, *Brookhaven National Laboratory.**—The neutron cross section of Fe has been investigated in the 4–14A region with the Brookhaven slow chopper at sample temperatures ranging from 100–1300°K. In the region above 450°K the temperature dependent part of the cross section (presumably inelastic scattering) is found to depart from the values calculated by Kleinman and by Placzek, whereas agreement is found for copper. The calculations are based on the exchange of energy between the neutrons and the lattice vibrations; the principal process for the wavelengths considered here being absorption of phonons by the neutrons. The departure of experiment from theory increases rapidly with temperature, and at the Curie point the inelastic scattering is twice the calculated value. The rate of change of cross section with temperature shows a marked decrease above the Curie point, and at all temperatures it is proportional to wavelength, as expected for inelastic scattering. It is concluded that the excess cross section is magnetic inelastic ("spin wave") scattering. The persistence above the Curie point, however, seems in direct conflict with the supposed paramagnetic nature (uncoupled spins) of iron at high temperature.

* Work carried out under contract with the AEC.

X6. Diffusion and the Motion of Phase in Binary Alloys. D. D. VAN HORN, *Knolls Atomic Power Laboratory.**—In the diffusion interchange between two "adjacent" phases in a binary alloy (for example, diffusion between α- and β-brass) it is generally observed that the position of the phase boundary relative to the initial interface will change with time. For unidirectional diffusion in an infinite specimen, it can be shown that the displacement of the phase boundary is given by $d=K(2t)^{\frac{1}{2}}$. If λ_1 and λ_2, the differences between the initial concentration (c) of each phase and the corresponding solubility limit (c_0) in that phase, and δ, the concentration difference between the two solubility limits ($\delta=c_{20}-c_{10}$) are given, then any two of the three quantities D_1, D_2, and K will determine the third. (D_1 and D_2 are the respective diffusion coefficients in the two phases.) The complete solution of the problem, including the analytical expressions for the concentration curves is determined by the solution of the following equations for β_1 and β_2:

$$\beta_1 D_1^{\frac{1}{2}} = \beta_2 D_2^{\frac{1}{2}} = K/\sqrt{2}, \tag{1}$$

$$\delta\pi^{\frac{1}{2}} = \lambda_2 \exp(-\beta_2^2)/[\beta_2(1+\operatorname{erf}\beta_2)] - \lambda_1 \exp(-\beta_1^2)/[\beta_1(1-\operatorname{erf}\beta_1)]. \tag{2}$$

A nomographic solution of these equations will be given.

* The Knolls Atomic Power Laboratory is operated for the AEC by the General Electric Company.

X7. Diffusion of Sodium in Sodium Tungsten Bronze. J. F. SMITH AND G. C. DANIELSON, *Iowa State College.*—An investigation of the diffusivity of sodium in single crystals of the metal sodium tungsten bronze is in progress. The concentration gradient is established by evaporation of sodium from a sample heated in a vacuum, and the sodium concentration is measured by x-ray determination of the lattice constant which varies linearly with sodium concentration. The diffusivity is evaluated by a method which is based upon Fick's first law rather than his second. The data give a family of curves showing the concentration as a function of depth with time as a parameter. From these curves the mass of sodium transferred through a plane parallel to the surface and at any particular depth may be plotted as a function of time. The slope of this curve divided by the concentration gradient, both evaluated at the same depth and time, is the diffusivity for the corresponding concentration. Preliminary results indicate that the diffusivity decreases with increasing sodium concentration.

X8. Some Observations on the "Direct-Current Etch." DAVID B. LANGMUIR, *Atomic Energy of Canada Limited.*—Tantalum, in common with a number of other metals, develops an etched appearance when heated with direct current in high vacuum at about 2200°K for 50 or more hours. This phenomenon has been investigated by using tantalum strips 0.001–0.005 inch thick in which crystal grains 1 mm or more in diameter have been grown. Goniometer reflections using visible light have been obtained within +5° from the surfaces developed by dc heating, and these surfaces have been identified by comparison with Laue back reflection photographs. In cases observed so far the initial surface of the strip has coincided within a few degrees with either a (110) or (211) plane. In the case of a (211) initial surface with the current flowing parallel to the close packed (111) direction, one face of the crystal grain remains almost smooth, while the opposite face develops a set of ridges running at right angles to the direction of current flow and bounded by (100) surfaces on the (+) side, (110) surfaces at the ends, and a (211) surface on the (−) side. When the close-packed direction makes an oblique angle to the direction of current, a (211) surface usually develops with its normal having a component pointing toward the negative end.

X9. Self-Diffusion of Tantalum. R. L. EAGER* AND D. B. LANGMUIR,† *Atomic Energy of Canada Limited.*—The volume self-diffusion of tantalum has been measured by activating a small volume of a tantalum strip in the thermal column of the NRX pile and heating in vacuum. The volume diffusion coefficient D_v over the range 2100 to 2800°K can be represented by the equation $D_v = 2\exp(-110{,}000/RT)$ cm²/sec. Auto radiographs show that grain boundary diffusion occurs much more rapidly than volume diffusion near 1800°K. Attempts have been made to measure the surface self-diffusion coefficient D_s by evaporating a surface deposit of radiotantalum upon a clean tantalum strip. Using the analysis developed by J. C. Fisher,[1] the results show that $D_s < 10^7 D_v$ at 1800°K.

* Now at the Chemistry Department, University of Saskatchewan, Saskatoon, Saskatchewan.
† USAEC Liaison Officer.
[1] J. C. Fisher, J. Appl. Phys. **22**, 74 (1951).

X10. Improved Techniques in the Aging of Thin Metal Films.* RICHARD B. BELSER, *Georgia Institute of Technology.*—It has been known for over a century that thin metal films change in optical properties, electrical resistivity, and structure with the passage of time or exposure to heat or corrosion. Whereas these properties were known, their exact delineation and quantitative evaluation have awaited improved techniques and instrumentation. Application of improved methods of soldering to thin metal films with the metal indium and its alloys, recognition of the importance of current distribution within the film, and development of a high temperature, infrared-oven, "aging" technique, which may be operated in a vacuum, have resulted in the obtaining of resistivities only slightly above that of the bulk metal for evaporated metal films of about 1000 angstroms thickness. Studies of silver, gold, aluminum, and copper films deposited by vacuum evaporation have been made. Studies of sputtered gold and silver are reported. The resistivity of evaporated films of the metals named deposited at 2×10^{-6} mm of mercury has been found to be about 1.3 bulk resistivity. For sputtered films it is about 1.5–2.0 bulk resistivity, dependent on sputtering rate and conditions. Aging effects are discussed.

* Supported by United States Army Signal Corps.

SATURDAY AFTERNOON AT 2:00

Crow Hall, 101

(R. N. VARNEY presiding)

Invited Paper

Y1. Detection of Weak Electron Paramagnetic Resonance. JONATHAN TOWNSEND, *Washington University.* (30 min.)

Luminescence

Y2. Sensitized Fluorescence Studies using a Photomultiplier Detection Method. ROBERT H. MCFARLAND AND ROBERT E. SWANSON, *Kansas State College.*—Work by Cario and Franck, Loria, Winans, and others has indicated the possibility of collisions of the second kind in which colliding atoms contribute kinetic energy to the excitation energy of the system. In mixtures of mercury and zinc and of mercury and thallium, transfers of 1.05 and 0.67 volts, respectively, have been observed. Experimental evidence has been obtained with mixtures of mercury and thallium to show that this effect is not one of double absorption. Also it is plausible to assume that this is not an effect attributable to collisions of thallium with metastable mercury atoms as postulated by Loria.

Y3. A Study of Intensity Variations in Sensitized Fluorescence. ROBERT E. SWANSON AND ROBERT H. MCFARLAND, *Kansas State College.*—Development of apparatus to make direct readings of low-level light intensities has made an investigation of the mechanisms of sensitized fluorescence possible. Measurements of the intensities of thallium lines emitted from a thallium mercury mixture when irradiated with mercury 2537 show a dependence of intensity on the temperature of both mercury and thallium. With the thallium temperature constant, thallium 3519, 3529 reach their maximum intensity at a lower mercury temperature than does thallium 3776. This may be explained in terms of the partial selection rule $\Delta J = 0$ and metastable mercury states. Thallium 5350, how-

ever, exhibits two maxima under the same conditions. This has been explained only in terms of the possibility of a memory process in the population of the thallium $2S\frac{1}{2}$ level.

Y4. Energy Transfer in Complex Solutions.* MILTON FURST AND HARTMUT KALLMANN, *New York University.*—High energy fluorescence in organic solutions with a single solute is mostly due to transfer of energy from the solvent to the solute molecules. This transfer occurs by some type of collision process. Further experiments adding a second solute (with smaller efficiency and longer wavelengths of fluorescence) gave the possibility of studying energy transfer in more detail. In such complex solutions an additional energy transfer by collision from the first to the second solute occurs. This was shown from the unusual shape of the intensity *vs* concentration curve. This displayed a maximum followed by a minimum and another considerable rise with increasing concentration of both solutes but with the concentration ratio constant. The decrease is caused by an absorption of the light from the first solvent by the second. The second rise occurs by direct energy transfer (without light absorption) from the first to the second solute; its probability increases with concentration even with constant solute ratio. A decrease of lifetime of the excitation energy in the first solute ensues from this energy transfer and reduces the chance of quenching the excitation energy in the first solute. Xylene solutions of *m*-terphenyl, anthracene, xanthone, dihydrocollidine, and fluorene were used.

* Work sponsored by the SCEL, Fort Monmouth, New Jersey.

Y5. A *K*-fluorescence Yield Summary. C. D. BROYLES* AND S. K. HAYNES, *Vanderbilt University.*—An accurate knowledge of the K fluorescence yield as a function of Z is sometimes essential in radioactive decay scheme problems. All previous summaries including recent ones by the authors and by Burhop[1] have not only been incomplete but also have contained several inaccuracies. The theory of K auger yield is also incomplete and approximate.

A brief review of the state of the theory will be presented. A summary of experimental values of the K-fluorescence yield will be given which we hope is accurate and complete to July 1, 1952. Copies will be available to those interested. A first summary of experimental values of the ratio of the $K-LL$ to the $K-LM$ plus $K-LN$, etc., yields will also be given. This summary includes previously published values plus that of indium[2] which is as yet unpublished.

* Now at Sandia Corporation, Albuquerque, New Mexico.
[1] E. H. S. Burhop, *The Auger Effect and Other Radiationless Transitions* (Cambridge University Press, Cambridge, 1952), pp. 45, 46.
[2] D. A. Thomas, Ph.D. thesis, Vanderbilt University (1952).

Y6. Cathodoluminescent Studies of (BaSr)O.* HAROLD W. GANDY, *University of Missouri.*—The cathodoluminescent properties of sprayed (BaSr)O samples on electrolytic nickel base metal are being studied as a function of sample temperature and sample thermionic activity. Spectral measurements show three bands to be present in moderately thermionically activated samples. Bands located at 310 mμ and 580 mμ have intensities which decrease with increasing temperature, and a band at 400 mμ has an intensity which increases with increasing temperature. Time decay of the cathodoluminescent intensity of each band is being studied as a function of sample activity and sample temperature. The time rate of decay of the luminescent intensity of each band increases with increasing temperature; however, the rate of decay of the 400-mμ band is less than that of the other two bands. The decay of the 400-mμ band appears to be exponential with time.

The intensity of the 400-mμ and 580-mμ bands seem to increase relative to the intensity of the 310-mμ band with increasing thermionic activity of the sample. The rate of decay of each band does not seem to be influenced by changing sample activity.

* Supported by a grant from the RCA Laboratories Division, Princeton, New Jersey.

Y7. (Abstract withdrawn.)

Y8. Characteristics of Thin Plastic Scintillation Phosphors. G. G. EICHHOLZ, *Department of Mines and Technical Surveys, Ottawa.*—Thin film plastic phosphors have been prepared by a modified pressure moulding technique in a cylindrical mould[1] or by pressing between aluminum sheets on heated platens. Optimum concentrations have been determined using polystyrene solutions of *p*-terphenyl and diphenyl hexatriene or tetraphenyl butadiene. Excellent light collection can be obtained with wedge-shaped phosphors. Results under alpha- and beta-irradiation and relative pulse-height distributions will be discussed. An outline will be given of possible applications in scintillation detectors for use with acid solutions and other cases where large-area detectors are desirable.

[1] G. G. Eichholz and J. L. Horwood, Rev. Sci. Instr. **23**, 305 (1952).

SATURDAY AFTERNOON AT 2:00

Wilson Hall

(HENRY PRIMAKOFF presiding)

Theoretical Physics

Z1. On Approximate Two-body Relativistic Wave Equations. Z. V. CHRAPLYVY, *St. Louis University.*—The Foldy-Wouthuysen method[1] has been extended to the two-body problem. A canonical transformation has been developed which converts any relativistic two-body Hamiltonian into an "even-even" operator, and thus makes it possible to obtain a four-component approximation to the 16-component wave equation with the negative-energy states of both particles excluded. This is especially important in the case of the Breit equation since, as has been pointed out,[2] the difficulties in its applications stem from an admixture of negative-energy states which, of course, are not removed in the large-component approximation usually applied to it.

[1] L. L. Foldy and S. A. Wouthuysen, Phys. Rev. **78**, 29 (1950).
[2] G. E. Brown and D. G. Ravenhall, Proc. Roy. Soc. (London) **208**, 552 (1951).

Z2. An Amplified Dirac Equation and the Lamb-Retherford Shift. W. A. BARKER AND Z. V. CHRAPLYVY, *St. Louis University.*—An amplified Dirac equation containing scalar, vector, tensor, pseudovector, and pseudoscalar interaction terms is converted to an approximately relativistic form by means of the Foldy-Wouthuysen[1] canonical transformation. The resulting relativistic correction terms associated with the five types of interaction are tabulated. Hydrogenic fine structure is discussed as an illustration of the utility of these tables. A relativistic wave equation in which appropriate factors of quantum electrodynamic origin[2] are included phenomenologically is rewritten in an approximately relativistic form. In this new representation one easily sees that the major contributions to the Lamb-Retherford shift are related in a simple way to the Darwin and Thomas corrections to the Balmer energy levels arising from ordinary Dirac theory. This method gives a value of 1062.59 mc/sec for the separation of the $2S$, $2P_{\frac{1}{2}}$ states of hydrogen. This phenomenological treatment, however, fails to yield the 4.00 mc/sec displacement of the $2P_{\frac{1}{2}}$ state.

[1] L. L. Foldy and S. A. Wouthuysen, Phys. Rev. **78**, 29 (1950).
[2] Karplus, Klein, and Schwinger, Phys. Rev. **86**, 288 (1952).

Z3. The Symmetry of the *S* Matrix. F. COESTER, *State University of Iowa.*—It can be shown that any Heisenberg S matrix is symmetric for an appropriate choice of arbitrary phases in a representation in which the square and one component of the total angular momentum are diagonal. The proof combines the theory of time reversal in quantum mechanics given by Wigner[1] with the methods of transformation theory. The consequences of this symmetry for the complex phases of the matrix elements are discussed.

[1] E. P. Wigner, Göttinger Nachr. **31**, 546 (1932).

Z4. The Pairing Property of Nuclear Interactions. G. RACAH, *Hebrew University, Jerusalem,* AND I. TALMI, *Palmer Physical Laboratory, Princeton University.*—Interactions of which the matrix elements have the form

$$(l^n, v, \Gamma | V | l^n, v', \Gamma') = \delta_{vv'}\{(l^v, v, \Gamma | V | l^v, v, \Gamma') + \delta_{\Gamma\Gamma'}(n-v/2)E_0\}$$

are said to possess the pairing property (p.p.). In this formula v is the seniority of the state of the configuration l^n specified by the additional necessary quantum numbers Γ, and E_0 is the energy of $l^n\,{}^1S_0$. In jj coupling the same formula holds in the j^n configuration if we replace l by j; E_0 is then the energy of j^2 $J=0$. This implies in particular that the seniority is a good quantum number. It is found that all the interactions which can be expressed as a sum of products of odd double tensors which operate on the spin and space coordinates of the two interacting nucleons, possess the p.p. in LS coupling as well as in jj coupling. An important central interaction of this kind is $W+2M$ which has the p.p. for any range and form of the potential. In the limit of short range, it goes over into the δ-potential, which is thus shown to possess the p.p. A noncentral interaction of this kind is that of the tensor forces.

Z5. A Lower Limit for the Interaction Time in Photon-Photon Scattering. E. GORA, *Providence College.*—In order to avoid difficulties which are the result of the use of sharp initial conditions in the time dependent perturbation treatment of radiation problems, a switching-on function has been introduced. This leads to the conclusion that the duration of the interaction, the "interaction time," should exceed a well-defined lower limit, or else the well-known formulas of the quantum theory of radiation could not be valid. For scattering of photons by electrons this lower limit turns out to be so small that it is not likely to be observable, but for photon-photon scattering its order of magnitude is $\gamma(\hbar c/e^2)^4(e^2/mc^3)$ $\sim\gamma\times10^{-18}$ sec, where $\gamma=\hbar\omega/mc^2\gg1$. The observed lifetime of a neutral meson decaying into two photons is of the same order of magnitude. This coincidence suggests an investigation of the possibility that the observed lifetime of unstable particles could be in some way linked up with a finite duration of the interaction between the particles which take part in the production and decay processes.

Z6. Photopion Production from a Single Nucleon. F. SALZMAN, *University of Illinois* (introduced by G. F. Chew).—The photopion production from a single nucleon is calculated in the symmetrical pseudo-vector coupling theory with a fixed extended source.[1] Only the free meson current is used in calculating the interaction between the nucleon-meson system and the electromagnetic field.[2]

The photon can be pictured as ejecting a π^+ from a virtual state in the proton cloud into a "real" particle scattering state. The high π^0/π^+ ratio corresponds to the large charge-exchange (π^+, N) scattering cross section. This process is examined in a weak-coupling approximation in which the initial and final wave functions are expanded to order g^3 in the pion-nucleon coupling constant. It is found that the secondary scattering effects are extremely important and dominate the terms of order eg^3. It is known that the perturbation treatment of the pion-nucleon scattering omits large reactive effects, but their inclusion by means of the Dancoff approximation only increases the relative importance of secondary scattering.[1] It is also noted that the terms of order eg^3 cannot be treated phenomenologically as resulting from a static or frequency dependent magnetic moment.

[1] G. F. Chew, Phys. Rev. (to be published).
[2] J. S. Blair and G. F. Chew, Ann. Rev. Nuclear Sci. **2** (1952).

Z7. A Variational Procedure for Electron-Hydrogen Scattering. M. M. GORDON AND J. G. JONES, *University of Florida.*—An improved variational procedure for $e-$H scattering has been developed whereby both the elastic and inelastic scattering amplitudes can be calculated directly. The derivation of this procedure follows from the "spatial-orientation degeneracy" of the wave function and the availability for computations of a complete ortho-normal set of H eigenfunctions.[1] This variational procedure has the following features: (a), it does not involve a partial wave analysis; (b), it includes exchange scattering; (c), it treats elastic and inelastic scattering within the same formalism; and (d), it yields the Born approximation in zero-order. Calculations are now in progress which utilize this procedure to obtain an improvement of the Born approximation for the elastic scattering of 100 to 900 volt electrons. A linear trial wave function of the following form is being used:

$$\Psi=[\{1+(B+Cr_{12})\exp(-r_1/a_0)\}\exp(i\boldsymbol{k}\mathbf{n}\cdot\mathbf{r}_1) + (A/r_1)\{1-\exp(-r_1/a_0)\}\exp(i\boldsymbol{k}r_1)]\exp(-r_2/a_0),$$

where A, B, C are variational parameters. The preliminary results of this work will be presented.

[1] W. Kohn, Phys. Rev. **74**, 1763 (1948), Sec III.

Z8. Variation Method in Quantum Statistics.* JOHN M. RICHARDSON AND WILLIAM M. MACDONALD III,† *U. S. Bureau of Mines.*—The statistics of the grand canonical ensemble can be expressed in terms of a variational function Θ which is simply related to the equilibrium pressure, when it is maximized under the constraints of normalization and constancy of temperature and chemical potential. Using the field-theoretic formulation (involving creation and annihilation operators defined in terms of a set of single-particle states) of the Hamiltonian and number of particles, it is possible to expand Θ in a series of terms containing successively higher orders of interaction and correlation. Neglecting all correlations and third- and higher-order interactions, we obtain an approximate Θ in which variations are to be made on the single-particle states and on the quantum distribution

functions concerned with the occupancy of each state. In the case of fermions, we obtain results then reduce to the usual Fermi-Dirac distribution in the limit of vanishing interaction and to Fock's equations in the limit of zero temperature. The boson case is formally similar. We will consider the quantum version of the cell method in the theory of liquids.

* Supported in part by the ONR.
† Now at Princeton University, Princeton, New Jersey.

Z9. Possible Inconsistency in Customary Use of Vectors. J. G. WINANS, *University of Wisconsin.*—For two vectors to be equal they must have the same magnitude, direction, and unit. A cross product or axial vector like area $A=s_1\times s_2$ has the unit square cm and is perpendicular to s_1 and s_2. In describing vector components by unit vectors i, j, k, it is customary to consider $ij=k$. If $i=1$ cm, $j=1$ cm, and $k=1$ cm, considering $ij=k$ leads to an inconsistency since vector ij has the unit square cm and vector k has the unit cm. A distinction should also be made between square cm, a unit of a vector quantity and cm^2 a unit of a scalar quantity. For a series representation of $f(x)$, if x is a vector, odd power terms are vectors and even power terms are scalars. To carry out the additions the square of a vector must be considered a dimensionless number and then $f(x)=$scalar$+$vector$+$quaternion.

Z10. On the Beta-Decay Interaction. JOHN M. BLATT, *University of Illinois.*—The decays of C^{10} and O^{14} show that there must be an admixture of a Fermi-type interaction. The comparative half-lives (ft-values) of the neutron, H^3, He^6, and O^{14} are used to estimate the relative strengths of the Fermi and Gamow-Teller interactions. Because of the new value of the end-point energy of He^6,[1] the ft-value of this decay does *not* give significant information about the interaction. The matrix element $(\int\sigma)^2$ for the H^3 decay is not known very accurately because of the unknown amount of admixture of ^1D and other states to the dominant ^3S state. However, it can be shown that $(\int\sigma)^2\lesssim 3$ as long as the ^3S state is present with at least 25 percent probability. This allows us to put an upper limit on the lifetime of the neutron. An experiment is suggested to determine uniquely the nature of the Fermi-type interaction (scalar or polar vector). The considerations given here do not say anything about the presence or absence of a pseudoscalar component.

[1] Dewan, Pepper, Allen, and Almquist, Phys. Rev. **86**, 416 (1952).

Z11. Special-Relativistic Linear Gravitational Theory. F. J. BELINFANTE, *Purdue University.*—Derive such theory (different from Birkhoff's) from the Lagrangian $\int dt(L_g+L_m)$;

$L_g=-(c^4/16\pi G)\int d^{(3)}\mathbf{x}G^{\alpha\beta}G^{\lambda\mu}G^{\rho\sigma}\{a(\partial_\alpha h_{\lambda\rho})(\partial_\beta h_{\mu\sigma})+b(\partial_\lambda h_{\mu\alpha})(\partial_\rho h_{\sigma\beta})+f(\partial_\alpha h_{\lambda\mu})(\partial_\beta h_{\rho\sigma})+q(\partial_\alpha h_{\lambda\mu})(\partial_\rho h_{\beta\sigma})\}$;

$L_m=\sum_i m_i c\{-w_i+Kw_iG^{\alpha\beta}h_{\alpha\beta}+Bh_{\alpha\beta}dx_i{}^\alpha dx_i{}^\beta/2w_i d\tau^2\}$;

$h_{\lambda\mu}=h_{\mu\lambda}$, $G_{\mu\nu}=G^{\mu\nu}=(1-2\delta_{\mu 0})\delta_{\mu\nu}$, $w_i=(-G_{\mu\nu}dx_i{}^\mu dx_i{}^\nu/d\tau^2)^{\frac{1}{2}}$, $\partial_\alpha=\partial/\partial x^\alpha$, $G=6.67\times10^{-8}$ cm^3 g^{-1} sec^{-2}, coefficients a, b, f, q, B, K chosen later. If $(2aq+q^2-4bf)/8K=a(b+2q)/B$ (say $=C$), the gravitational equations around mass M have static spherical solution $h_{\mu\nu}=\{(b+q)G_{\mu\nu}-(b+2q)\delta_{\mu\nu}\}GM/2c^2Cr$. Equations of motion for particles in such field yield Kepler orbits, if $4C=4Kb-2Bb-3Bq$, with perihelion precession $=N\pi MG/c^2a(1-\epsilon^2)$ with $N=-(6Bb+13Bq+4Kb)/4C$. First terms in expansion of Einstein's Lagrangian in powers of $h_{\mu\nu}=g_{\mu\nu}-G_{\mu\nu}$ and $k^{\mu\nu}=g^{\mu\nu}-G^{\mu\nu}$ are the above with $B=-4a=2b=4f=-2q=1$ and $K=0$. This gives $N=7$. For finding Einstein's $N=6$, Einstein's theory requires the terms cubic in $h_{\mu\nu}$ and $k^{\mu\nu}$ in L_g (which adds 1 to N) and terms quadratic in $h_{\mu\nu}$ in L_m (which subtracts 2). We adjust N to its experimental value by convenient choice of a, b, f, q, B, K satisfying above conditions. ($B=0$ won't do.) Energy-momentum 4-vector for particle $p_\mu=mcU^\nu\{G_{\mu\nu}-KG_{\mu\nu}G^{\alpha\beta}h_{\alpha\beta}+Bh_{\mu\nu}+\frac{1}{2}BG_{\mu\nu}h_{\alpha\beta}U^\alpha U^\beta\}$ with $U^\mu=dx^\mu/wdt$ satisfies $dp_\mu/wdt=f_\mu/c\equiv mc\{\frac{1}{2}BU^\alpha U^\beta+KG^{\alpha\beta}\}\partial_\mu h_{\alpha\beta}$. In a static central field p_0 and $\mathbf{r}\times\mathbf{p}$ are conserved.

Z12. The Quadrupole Moment of Li^7. E. G. HARRIS,* *The University of Tennessee,* AND M. A. MELKANOFF, *University of California at Los Angeles* (introduced by R. D. Present).—The quadrupole interaction energy, eqQ, for Li^7 in Li_2 has been reported to be positive.[1] In an attempt to determine $Q(Li^7)$ a calculation of q has been made using two approximate wave functions for Li_2. One of these is a Heitler-London function including inner shells and the other a 12 term variational function[2] which gives a dissociation energy 0.6 ev less than the experimental value. The results of the two calculations differ in sign. The more accurate James function leads to a negative q and consequently a negative value of $Q(Li^7)$. Unfortunately, the electronic and nuclear parts of q are nearly equal in Li_2 so that the magnitude and even the sign are still uncertain.

* AEC Predoctoral Fellow.
[1] Logan, Cote, and Kusch, Phys. Rev. **86**, 280 (1952).
[2] H. M. James, J. Chem. Phys. **2**, 794 (1934).

SUPPLEMENTARY PROGRAMME

SP1. A Technique of Soldering to Thin Metal Films.*† RICHARD B. BELSER, *Georgia Institute of Technology.*—In the past, soldering to thin metal films on glass or quartz substrates has normally been accomplished by suitably reinforcing the film at the soldering point with a thicker underlying film. This performance is necessary in order to prevent tin-lead solders and commonly used fluxes from destroying the film and to give better adhesion to the substrate. It has been found that by using the metal indium and certain of its alloys as a solder, without a flux, adherence to thin metal films may be readily obtained without destruction of the film. Since indium also adheres to glass, quartz, ceramics, and silicious minerals the strength of the joint is not determined by the strength or adherence of the metal film but by the strength of the indium-glass or indium-quartz bond. Thus, films of only a few angstroms in thickness may be soldered without damage, with good mechanical strength and electrical contact. The strength of the bond is usually about 500 pounds per square inch. This technique has been found most useful in studying the resistivities of thin metal films and in the mounting of metal coated piezoelectric crystals. Soldered connections have been made to films of 18 metals including aluminum, titanium, and zirconium.

* Supported by United States Army Signal Corps.
† To be called for at the end of Session X if the Chairman rules that time permits.

SP2. The Frictional Adhesion of Metal to Glass, Quartz, and Ceramic Surfaces.* RICHARD B. BELSER, *Georgia Institute of Technology.*—In 1947, W. A. Wooster and G. L. McDonald[1] reported that titanium by frictional contact would adhere to glass and certain mineral and ceramic surfaces. In order to explore this property further small disks of a number of different metals were mounted separately on one-eighth-inch shafts. These disks, driven by a high speed hand-grinder, were applied to glass, quartz, and ceramic surfaces. By suitably varying the rpm of the motor and the pressure of application, the metal of the disks could be made to adhere securely to such surfaces. At high rpm and moderate pressure, erosion of the glass surfaces usually occurred. Variations of the technique of application allowed the metallic coating or the cutting of glass. The coating method has been found useful for marking glassware, decorative work, metal to nonmetal seals, and for the application of electrically conducting lines to nonmetallic surfaces. Some of the metals tested were titanium, zirconium, aluminum, magnesium, gold, silver, copper, iron, nickel, cobalt, cadmium, zinc, and lead. Titanium and zirconium appeared to be the most active in glass cutting. For decorative and other purposes a number of the metals tested proved useful.

* To be called for at the end of Session X if the Chairman rules that time permits.
[1] W. A. Wooster and G. L. McDonald, Nature **160**, 260 (1947).

SP3. New Theory of Aggregates as Supplement to van't Hoff's Theory of Solutions.* GEORGE ANTONOFF.—This year the centenary of van't Hoff is celebrated. His theory of solutions has one limitation: It is valid only for dilute solutions, because in concentrated ones the van der Waals forces come into play. If supplemented by the new theory of aggragates,[1] it becomes valid at all concentrations. van der Waals theory fails on quantitative side, but he himself changed his views as is seen from his last paper, in which he has made a concession towards recognition of aggregates.[2] According to the new theory of aggregates, $X = d_1/d_v$ is the association factor, where d_1 is the density of the liquid and d_v that of vapor. Introduced into the gas equations X makes them comfortable with the laws of thermodynamics: The van der Waals forces are consumed in forming the aggregates and do not make themselves felt. Thus, the gas laws show themselves exact. The concept "activity" introduced by G. N. Lewis as a matter of expediency should be abandoned as having no physical meaning. On the contrary X introduces clarity and simplicity into this theory which shows itself in perfect agreement with experimental evidence.

* To be called for at the end of Session H if the Chairman rules that time permits.
[1] Jerome Alexander, Colloid Chem. **VII**, 83 (1950).
[2] See reference 40 of reference 1.

SP4. Kinks in Vapor Pressure p *vs* Temperature Curves.* GEORGE ANTONOFF.—The p curves show the same kinks as d_v. The values of the National Bureau of Standards are distrusted as being "smoothed," although without justification. They reveal the same law as the 30 liquids of Young. The RP 1229, 1939, gives water values for every 5 degrees. The smoothing could affect only points nearest to the kinks, but it could not mask the law. Paper No. 300 from Massachusetts Institute Technology gives in Table I, pages 154–163, figures *actually* observed mostly for every 10°C. I found the same kinks as in d_v curves. In Table V, page 166, values of p are computed for every degree. All points of Table I found in Table V remained unchanged. The kinks appear as intersections of two curvatures, although not as sharply as in the d^1 method. It is clear that they cannot be the result of "smoothing," which affects only the last figures but not those revealing the law.[1]

* To be called for at the end of Session H if the Chairman rules that time permits.
[1] See Smith, Keyes, and Gerry, Proc. Am. Acad. Arts Sci. **69** (January 1934).

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